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ORIGINAL ARTICLES.

I.—Eocene Corals from the Fly River, Central New Guinea.

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(PLATES XIX-XXII.)[1]

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DURING the expedition in 1889 and 1890 by the Right Hon. Sir William Macgregor, G.C.M.G., etc., up the Fly River, the largest river in New Guinea, he made a collection of fossil corals and limestones which he has entrusted to us for description. The specimens are rolled pebbles collected from the bed of the river, which flows between alluvial banks through low forest-clad country. Rocks were only exposed in occasional bars across the river, and there is no evidence as to their succession or dip.

The narrative of the expedition by Sir William Macgregor (1890, p. 56)[2] records the occurrence of pebbles of petrified coral, flint, and limestone, at a little south of Macrossan Island, at the latitude of about 6° 5′ S. He records limestone also at 5° 40′ S., at the confluence of the Black River with the Palmer, which is the chief upper tributary of the Fly River. Sir William Macgregor considered it possible that the pebbles might have been washed down from the lofty mountain chain which he discovered at the head of the Palmer River, and which includes Mt. Blücher in German New Guinea and Mt. Donaldson within British territory. The pebbles do not, however, appear to have travelled far down-stream, and the record in Sir William Macgregor's journal of the association of flint, limestone, and petrified coral below Macrossan Island suggests that the collection was made there. It consists of specimens of compact coral limestone, in which the coral material is brown, while the matrix is cream-coloured. One specimen (No. 20) consists of white limestone, and in it many of the loculi of the coral are empty; it may be younger in age than the rest of the collection. There are some fragments of white compact chert, in which the sections cut show no definite organisms; also a silicified coral, and a series of foraminiferal limestones, which are being investigated by Mr. R. B. Newton.

[1] Plates XIX and XX accompany Part I, and Plates XXI and XXII will appear with Part II of this paper in the December Number.

[2] A full summary of the narrative is given in Dr. Thomson's useful work, *British New Guinea*, 1892, pp. 117–54.

The bulk of the corals and the foraminiferal rocks appear to have come from the same limestone, which is of Eocene and probably of Middle Eocene age. The cherts are probably Upper Cretaceous. The map in Mr. Gibb Maitland's valuable but often overlooked memoir (1893, Map No. 3) colours the whole of the country along the Fly River, even to the north of 6°, as "recent superficial deposits", for the rock exposures on the river bed would be too small to be shown on that map.

Coral limestones have been repeatedly recorded from the interior of British New Guinea, but the references to them in the literature convey the impression that they have been regarded as young raised reefs, and therefore evidence of a great uplift in recent times. Mr. Gibb Maitland records the coral limestones on the Aird River in latitude 7° 10′ S. as "raised coral reefs"; and the same view has been adopted (e.g. Gibb Maitland, 1893, p. 63) for limestones as much as 2,000 feet above sea-level. The Eocene age of Sir William Macgregor's corals suggests that the higher coral limestones may be older than has been supposed. Dr. Logan Jack (1894, pp. 93, 94) has identified a fossil collected by Sir William Macgregor from the Purari River as a Cretaceous Belemnite. The genus *Actinacis*, which is represented in the collection by two species, is more frequent in the Cretaceous than the Eocene; the specimens of *A. maitlandi* are identical in lithological character with the brown Eocene corals and are doubtless Eocene. The other *Actinacis* we identify as *A. sumatraensis* (Tornq.); it is in a white chert and is probably Cretaceous.

The list of species is as follows:—

Feddenia sp.
Circophyllia sp.
Stylina macgregori, n.sp.
Stylophora papuensis, n.sp.
Leptoria carnei, n.sp.
Plesiastræa horizontalis, n.sp.
Dachiardia macgregori, n.sp.
Kobya hemicribriformis, n.sp.
Actinacis maitlandi, n.sp.
A. sumatraensis (Tornq.).
Porites deshayesana, Mich., var. *inequisepta*, n.var.
Porites sp.
Montipora antiqua, n.sp.

Systematic Description.

The collection includes three simple corals which are shown by the abundant dissepiments to be Astreans; but as only transverse sections are available the material is inadequate for specific description.

Feddenia, Duncan, 1880.

Two specimens (Nos. 17 and 21) have flattened sides, paliform lobes to the two first orders of septa, and have no columella; they agree with *Feddenia* from the Ranikot group, Lower Eocene, Sind. The diameter of the corallites is 10 × 15 mm. In No. 17 the number of septa is forty. Both specimens occur in a yellow foraminiferal limestone.

Circophyllia, Ed. & H., 1848.

This coral (No. 25) has an elongated cross section with parallel sides and rounded corners. The walls are thin. The columella is large and trabecular. There are no pali. The coral is therefore clearly a *Circophyllia*, which is a typically Eocene genus. A small incomplete

section on the same specimen shows a strong resemblance to the figure by Reis (1890, p. 108, pl. iv, fig. 17) of his *Desmopsammia perlonga*, for it has broken thin irregular septa, on which occur triangular paliform expansions. The section is, however, probably across a young *Circophyllia* in which the septa are thin and incomplete, and the columella is represented only by isolated trabeculæ from the septa.

STYLOPHORA, Schweigger, 1819.

Stylophora papuensis, n.sp. (Pl. XX, Fig. 3.)

Diagnosis.—Corallum compact and formed of tufts of crowded branches which are circular in transverse section except near their bifurcations, where they give rise to elongated or dumb-bell sections. The branches are usually hollow. Surface granular and punctate. Corallites small and rounded. Calices arranged irregularly and sparsely, their distance apart being generally greater than the diameter of the corallites. They are shallow and their margins are flush with the surface of the corallum and show no sign of a raised rim. Septa six in number and regular in arrangement; they are thick and joined to the columella. No secondary septa. Columella prominent.

Dimensions.—Corallum, 45 long, 60 broad, 30 mm. thick; diameter of branches, 3–4 mm.; diameter of corallites, ·6 mm.; distance of calicinal centres, 1–2 mm.

Figures.—Pl. XX, Fig. 3, part of surface of corallum, $\times 1\frac{1}{2}$ diam.

Affinities.—*S. papuensis* show a close resemblance to the Eocene species *S. rugosa* (d'Arch.),[1] agreeing with the latter in the size and irregular arrangement of the calices, in the prominent columella, and the granular surface. It differs, however, by having neither secondary septa nor rim around the calices.

Stylophora has a wide range through the Kainozoic limestones of Sind. Duncan has thence described four species. Of these *S. contorta*, Leym., from the Khirthar Series (Duncan, 1880, p. 61, pl. xviii, figs. 21, 22) is widely distributed through the Eocene; it is distinguished from *S. papuensis* by having more crowded and larger calices and conspicuous secondary septa. The nearest Indian species is the *S. pulcherrima*, Ach., which has been described from Sind by Duncan (1880, p. 73, pl. xv, figs. 12, 13) in the Nari Series, which he correlated with the Oligocene or Upper Eocene. The Sind representative of the species agrees with *S. papuensis* by having a granular surface and only six septa; but in *S. pulcherrima* the corallum is flat and massive instead of being dendroid. Of the two Miocene species from Sind, *S. minuta*, Duncan (1880, p. 83, pl. xxiii, fig. 6, originally described by Duncan from the West Indies) has a smooth surface and more distant calices, each of which is surrounded by a thick circular rim; while *S. confusa*, Duncan (1880, p. 83, pl. xxiii, fig. 7) has crowded calices, a nodular corallum, and the intercalicinal distance is only about 1 mm.

[1] D'Archiac, 1847, p. 1010; 1850, p. 403, pl. viii, fig. 7.

STYLINA, Lamarck, 1816.

Stylina macgregori, n.sp. (Pl. XIX, Figs. 1*a*, *b*.)

Diagnosis.—Corallum massive, with a subplane upper surface. Calices irregularly distributed and irregular in shape. They are shallow and sunk between broad ribbon-like and apparently solid walls, over which the costæ were no doubt continued as prominent lines. Septa three cycles. The primary septa are much thicker than the others and very conspicuous. The hexameral symmetry of the septa is usually complete. Both secondary and primary septa join the columella; but the secondary septa are much thinner than the primary.

Dimensions.—Fragment of corallum, length, 60 mm.; width, 30 mm.; corallites, diameter, 4–5 mm.; calicinal centres, average distance, 8 mm.

Figures.—Pl. XIX, Fig. 1*a*, part of the upper surface of the corallum (No. 27), magnified 3 diameters; Fig. 1*b*, part of a polished surface of the same specimen, magnified 3 diameters.

Affinities.—This species, owing to its septal plan, belongs to the same group as the type of the genus, *S. echinulata*, Lam., from the Middle Oolite, but its calices are much larger. The most conspicuous feature in the species is the prominence of the primary septa, whereby it has a striking external resemblance to a Miocene coral from Egypt—*Stylophora asymmetrica* (Gregory, 1898, pl. viii, fig. 4); but the transverse section, Pl. XIX, Fig. 1*b*, shows, however, that there is no true cœnenchyma, and that the coral is one of the Stylinidæ. The species, owing to the conspicuousness and irregularity of the primary septa, the continuation of the costæ over the thick wall, and the thickness of the columella, also remarkably resembles a coral from the Pliocene of Java described by Felix (1913, p. 336) as *Siderastræa micrommata*. The transverse section of the coral shown by Felix (ibid., fig. 3) seems to us to prove that it is not a *Siderastræa*, the intimate structure of which has been well represented in sections by Dr. Ogilvie (1895, p. 181). Felix's *S. micrommata* appears to have the characteristics of a true *Stylina*. It differs, however, from the species collected by Sir William Macgregor, since the corallites are more crowded and are only from $1\frac{1}{2}$ to 2 mm. in diameter. The nearest ally of *S. macgregori* is *Stylina tertiaria*, Duncan (1880, p. 61, pl. vi, figs. 1, 2), from the Khirthar Series of Sind. The two species agree by the great length of the costæ and the spacing of the corallites. But they differ in that *S. tertiaria* has only two complete cycles of septa and as its primary septa lack the unusual thickness of its New Guinea ally.

It is advisable also to compare the coral with *S. reussi*, Duncan, from the Lower Eocene or Ranikot Series of Sind (Duncan, 1880, p. 30, pl. x, fig. 11). But in that species the corallites are smaller, being only 2 mm. in diameter; they are very irregularly spaced and have less conspicuous primary septa. *S. macgregori* of Sind therefore agrees better with the Upper Eocene than with the Lower Eocene species from Sind. The matrix of this specimen differs from that of other corals as it is white and contains open spaces; it may therefore come from a different horizon.

LEPTORIA, Ed. & H., 1848.

Leptoria carnei,[1] n.sp. (Pl. XIX, Figs. 2 and 3.)

Diagnosis.—Corallum, external form unknown. Calicinal valleys long, and branching rather angular; they are irregularly arranged. Corallites, walls vary in thickness from a mere line which is no thicker than a dissepiment to that of the thickest part of the septa. Dissepiments most abundant nearest the walls. Septa, serration very slight; all the septa in a considerable series are often equal in thickness. Septa become thicker distally and end in a cross-shaped T-piece, the length of which is from two to five times the thickness of the adjacent part of the septum. Columella irregular in thickness; in places only as thick as the thinnest part of the septa; it may then be discontinuous, but it is usually a continuous lamina, and its thickness may be equal to the thickest part of the septa.

Dimensions.—Length of calicinal valleys, 16–35 mm.; breadth of calicinal valleys, 8–15 mm.; septa, about 10 in 10 mm.

Figures.—Pl. XIX, Fig. 2, part of a polished surface (No. 6 type-specimen) showing the well-defined narrow wall with abundant adjacent dissepiments, and, opposite the arrow, the T-shaped ending of the septa and the thin, irregular columella; × 3 diam. Fig. 3, part of another specimen (No. 7 co-type) showing (beside the two dots) the conspicuous wall; in the centre of the figure the expanded ends of the septa are cut through obliquely, and the columella is thin and discontinuous; the dissepiments are especially numerous; × 3 diam.

Affinities.—The equality of the septa at first suggests comparison of this species with the *Meandrina equisepta*, Gregory (1900, p. 212, pl. xix, fig. 2), from the Miocene of Christmas Island, but that coral has the columella of a true *Meandrina* (using the name *Meandrina* in the sense of Edwards & Haime, and not of its original founder, Lamarck).

An Indian coral which was described by Duncan (1880, p. 39, pl. vi, figs. 11, 12) as *Diploria flexuosissima*, D'Arch., is suspiciously like the species in its septal characteristics, but the Sind coral has the separated walls of *Diploria*. Duncan's *Meandrina medlicotti* (1880, p. 77, pl. x, figs. 15, 16), from the Nari Series (Oligocene), is, however, not a *Meandrina*, but a *Leptoria*, as it has a very thin laminar columella; it differs from *L. carnei*, which is its nearest ally, by its calicinal valleys being far more sinuous, its wall thicker, and the adjacent septa, though sometimes equal, usually being alternately large and small; it has, moreover, about forty septa to the inch. *L. concentrica*, Duncan (1880, p. 87, pl. xxiii, figs. 1, 2), which ranges from the Khirthar or Nari Series to the Gaj, differs by having the septa alternately large and small, while the inner ends of the larger septa are club-shaped rather than T-shaped. *L. radiata*, Michelin (1847, p. 294, pl. lxviii, fig. 3), from the Craie tuffeau (Turonian, Baines de Rennes), has long, straight calicinal valleys, which give the corallum its radiate aspect, and its septa are four to 1 mm.

[1] Named after Mr. J. E. Carne, of Sydney, in recognition of his valuable additions to the geology of New Guinea, as well as of his many important contributions to that of Australia.

DACHIARDIA, Duncan, 1880.

Dachiardia macgregori, n.sp. (Pl. XX, Figs. 2*a*, *b*.)

Diagnosis.—Corallum nodular; growth irregular; in places the surface is subplane and granular. The calices are widely isolated by compact exothecal tissue. Elsewhere the corallites project above the surface and are therefore free laterally; and the formation of younger similar surfaces has left spaces filled with matrix in which the corallites are laterally free. Corallites circular, subcircular, and sub-hexagonal; often long and straight; fission exceptional. Septa two complete cycles which are long and join the columella, and occasional representatives of a third cycle. Endotheca scanty. Columella small but distinct. In some sections it appears even styliform. Pali indistinct, occurring as paliform lobes.

Dimensions.—Diameter of corallum, about 50 mm.; diameter of corallites, 2–4 mm.; distance of calicinal centres, 5–7 mm.

Figures.—Pl. XX, Fig. 2*a*, part of upper surface of corallum showing corallites and granular surface; × 3 diam. Fig. 2*b*, part of same specimen, showing transverse section of a corallite; × 2 diam.

Affinities.—This interesting coral raises the question of the affinities of the genus *Dachiardia* which, when founded by Duncan in 1880, was placed next to *Plesiastræa*; he, however, remarked at the end of the diagnosis (p. 92), "Fissiparity occurs, but is rare." Subsequently in his Revision (1884, p. 101) he placed the genus amongst the fissiparent Astreans, in the alliance *Favoidea*. His figures of *D. densa*, the first of the two species which he included in the genus, show no clear evidence of growth by fission. The figure of his second species, *D. lobata*, gives clearer evidence of that mode of growth, and is therefore the most convenient type of the genus; we select it since none has been previously nominated.

D. lobata differs from *D. macgregori* by having twenty-four septa which are alternately large and small, so that the cycles do not retain their hexameral symmetry. The calices in *D. lobata* are from 2 to 2½ mm. in diameter, and are therefore only half the size of those in *D. macgregori*. *D. densa* differs by having smaller corallites and three cycles of septa, which, being relatively longer, appear far more crowded than in *D. macgregori*. *D. densa* also has more definite pali.

PLESIASTRÆA, Ed. & H., 1848.

Plesiastræa horizontalis, n.sp. (Pl. XX, Figs. 1*a*, *b*.)

Diagnosis.—Corallum compact, nodular. Outer surface unknown. Corallites circular to subcircular; long, straight, and parallel. They are united by horizontal dissepimental exotheca which gives a tabulate aspect to vertical sections, but may not be visible in cross-section. Septa three complete cycles, all short; in those of the third cycle the costæ are sometimes twice as long as the corresponding septa. Pali two crowns forming a regular well-defined circle around the small fascicular columella. The secondary pali are no larger than the primary. Endotheca scanty.

Dimensions.—Diameter of corallites, 3 mm.; distance of calicinal centres, 5 mm.; diameter of circle of pali, 1·5 mm.; average vertical distance between horizontal exothecal dissepiments, 5 mm.

Figures.—Pl. XX, Fig. 1*b*, part of a transverse section of specimen No. 18; × 3 diam. Fig. 1*a*, part of a vertical section of the same specimen, showing the horizontal exothecal dissepiments; × 3 diam.

Affinities.—This species is represented in the collection by four specimens (Nos. 9, 10, 18, 19), in some of which, however, the septal structure has been destroyed. Duncan has described a species, *P. eocenica* (1880, p. 66, pl. xix, figs. 8–10), from the Upper Khirthar or base of the Nari Series in Sind; it has more numerous septa, though the fourth cycle is not complete; the septa of the third cycle are much longer and the corallites larger than in *P. macgregori*.

The well-known European Miocene species *P. desmoulinsi*, Ed. & H., 1851, has several resemblances to *P. macgregori*; but it has a more compact exotheca and its primary pali are smaller than the secondary pali.

The specific name in *Heliastræa tabulata*, Martin (1880, p. 140, pl. xxiv, fig. 21, and pl. xxvi, fig. 4), from Java, suggests comparison with this species; but Martin's illustrations show that his species is not a *Plesiastræa*.

KOBYA, Gregory, 1900.

Kobya hemicribriformis, n.sp. (Pl. XXI, Fig. 4.)

Diagnosis.—Corallum massive; external shape unknown. Corallites very large, closely crowded. Septa in four cycles which are generally complete. The primary septa are large and thickened with a paliform expansion at the inner end. Similar expansion and thickening also occur in some of the secondary septa, which are as long as the primary. The columella is large and it occupies a sixth of the diameter of the corallite. The alternate septa are usually cribriform and appear in sections as rows of isolated trabeculæ; but in some of the younger corallites, owing apparently to a secondary thickening, all the septa may appear solid.

Dimensions.—Fragment of the corallum, No. 35, length, 70 mm.; width, 5·5 mm.; thickness, 40 mm.; diameter of corallites, 12–14 mm.; distance of calicinal centres, 12–22 mm. (average 15 mm.).

Figure.—Pl. XXI, Fig. 4, part of polished surface; nat. size.

Affinities.—This interesting coral is represented in the collection by six specimens (Nos. 30–5). They all appear to have come from the same bed, as they are in a light yellow limestone in which the matrix is paler in colour than the coral. The generic position of this coral is not free from doubt owing to uncertainty in definition of two genera. Dr. Andrews collected in the Miocene rocks of Christmas Island a small fragment of a coral which was included in *Coscinaræa*, as among the genera then established it was nearest to it, and the material was inadequate for the establishment of a new genus. The coral from New Guinea probably belongs to the same genus. Though the synapticulæ are scarce, they are quite distinct, and there can be no doubt that the coral is a compound fungian in which some of the septa are cribriform. The coral resembles the Jurassic *Kobya*, which, as shown by *Kobya crassolamellata*, Gregory (1900, pl. xxiii, fig. 2*c*), has the same fascicular columella and alternation of solid and cribriform septa; but in the Jurassic *Kobya* the trabecular structure of the septa is more regularly developed.

The genus *Coscinaræa* has always appeared out of place in the *Agaricioida*, in which Duncan placed it; and the characters which led to its reference to that alliance appear to be unessential features due to habit of growth. The characters of the septa show that *Coscinaræa* is allied to the Jurassic genus *Kobya*. Owing to the kindness of Professor Stanley Gardiner we have been able to examine a series of specimens of *Coscinaræa*, including some of the type species of the genus. *Coscinaræa* appears to us to be a descendant of *Kobya*, in which the corallum, instead of being massive, is an encrusting lamina, and in which the corallites tend to occur in short series separated by raised bands that have sometimes the aspect of collines. The columella is small and deep.

In *Kobya* the corallum is massive, the calices are separated by flat surfaces traversed by septocostæ, the columella is large and, though parietal in structure, it may end above as a single papilla. The species of *Kobya* which most closely approaches *Coscinaræa* is *K. lenticulata* (Gregory, 1900, p. 172, pl. xxii, figs. 3, 4), in which the corallum is flat and lenticular. Its corallites tend to grow in concentric series with slightly raised edges; its corallum is, however, massive, and this species only indicates a tendency towards the characters of *Coscinaræa*. That genus is one of the distinctive corals of the Indian Ocean and Red Sea, and the occurrence of *Kobya* in Bathonian and Eocene times in the same region is geographically consistent with the suggested relationship between the two genera.

C. andrewsi, the Miocene species from Christmas Island, was described as "apparently massive". It will therefore probably be found, when better specimens of it are available, to be a *Kobya*. It differs specifically from *K. hemicribriformis* in that the corallites are much smaller; in the Christmas Island species the corallites are only 10 mm. and the columella 2 mm. in diameter, whereas in *K. hemicribriformis* they are respectively 15 and 3 mm. in diameter.

EXPLANATION OF PLATES.

PLATE XIX.

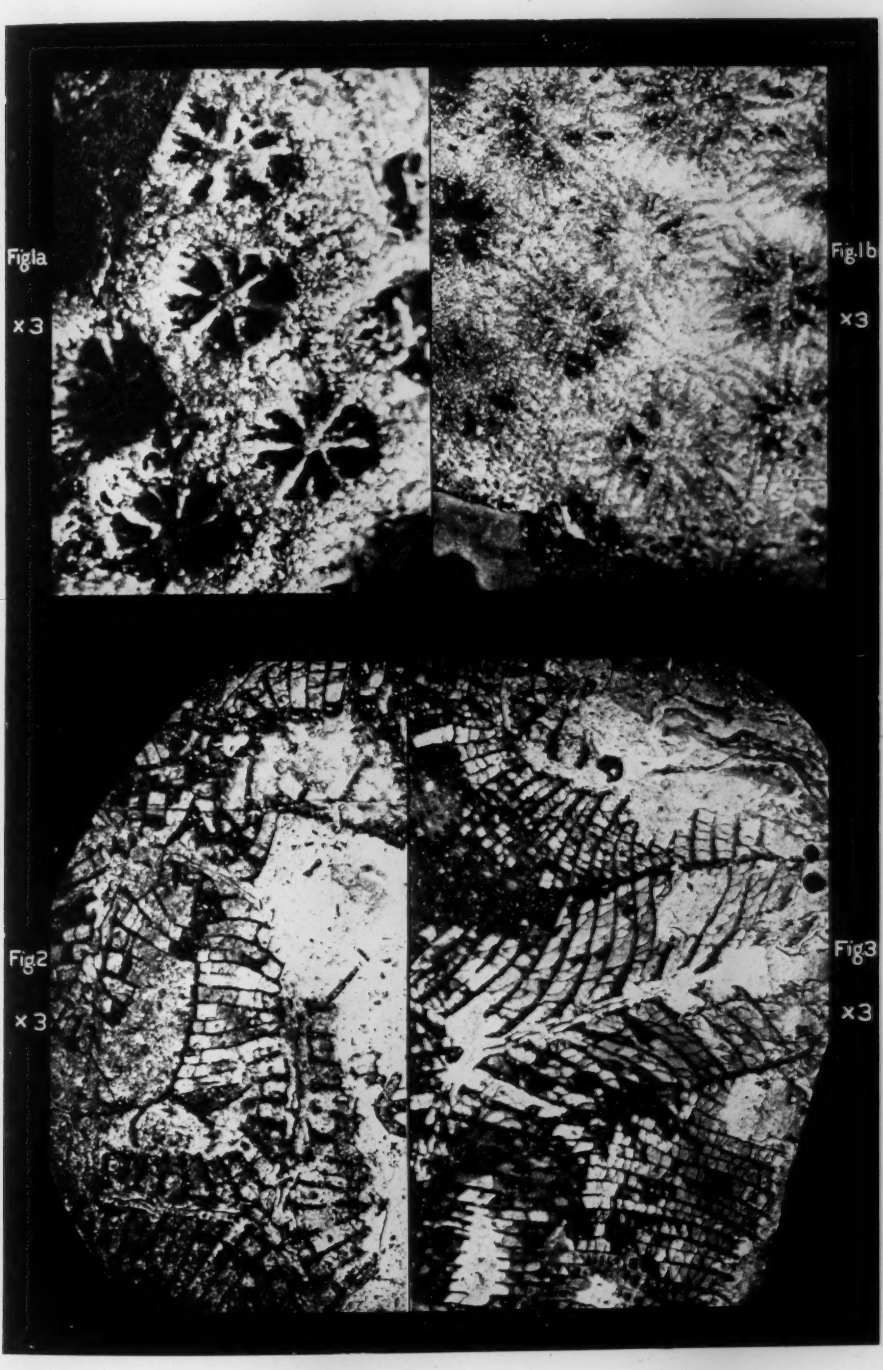
FIG.

1. *Stylina macgregori*, n.sp. No. 27. Fig. 1*a*, part of upper surface of corallum, × 3 diam.; Fig. 1*b*, part of polished surface of same specimen, horizontal section, × 3 diam.
2. *Leptoria carnei*, n.sp. No. 6. Part of polished surface of corallum, × 3 diam.
3. *L. carnei*, n.sp. No. 7. Part of polished surface of corallum, × 3 diam.

PLATE XX.

1. *Plesiastræa horizontalis*, n.sp. No. 18. Fig. 1*a*, part of polished surface of corallum, vertical section, × 3 diam.; Fig. 1*b*, part of polished surface of same specimen, horizontal section, × 3 diam.
2. *Dachiardia macgregori*, n.sp. No. 5. Fig. 2*a*, part of corallum showing a few corallites and granular surface, × 2 diam.; Fig. 2*b*, part of polished surface of same specimen, × 2 diam.
3. *Stylophora papuensis*, n.sp. No. 22. Part of surface of corallum, × 1½ diam.

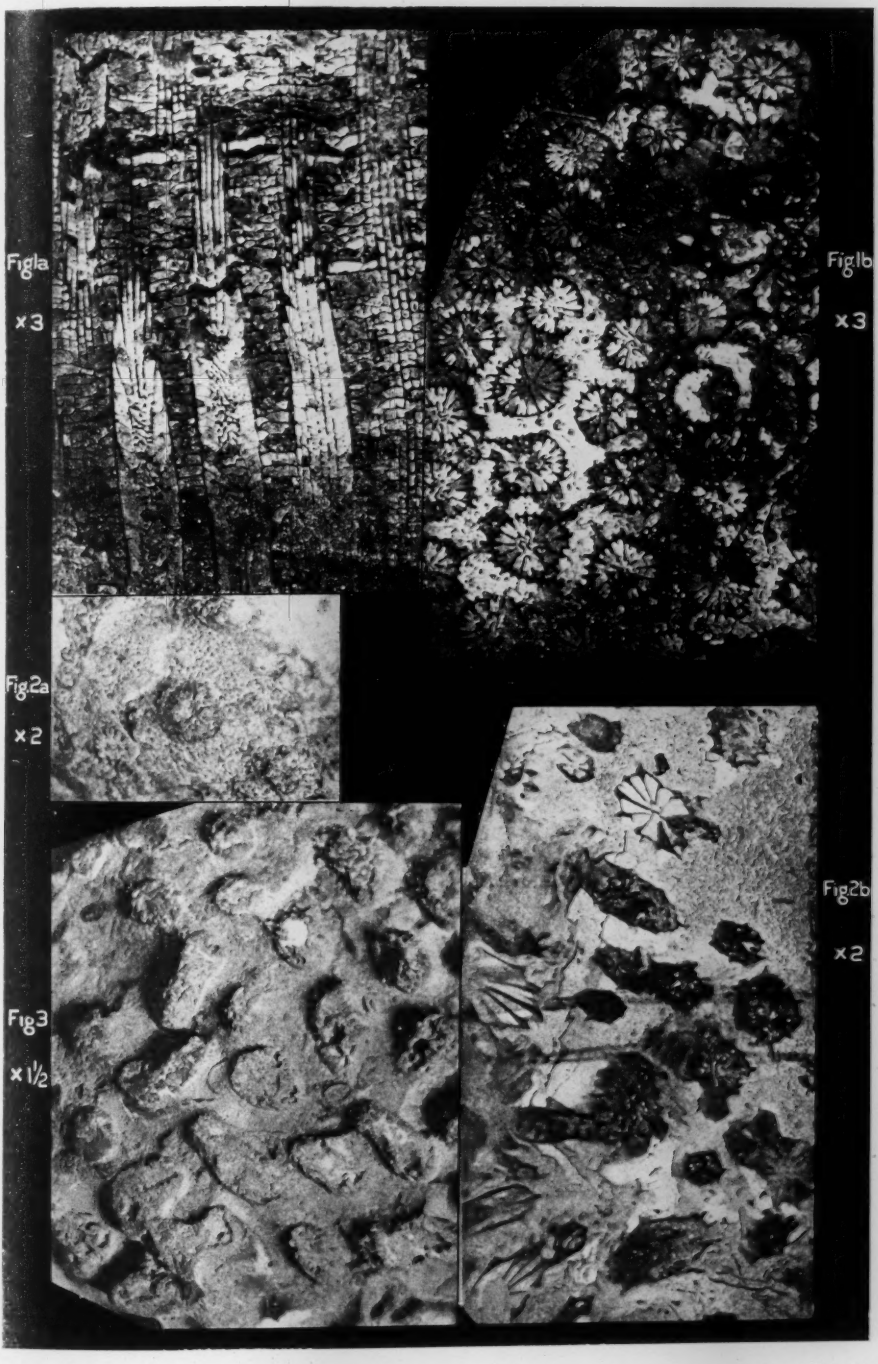
(*To be concluded in our next Number.*)



Photos by S. Fingland. *Gregory & French.*

EOCENE CORALS, NEW GUINEA.

Stylina *Leptoria.*



Photos by S. England. Gregory & Trench.

EOCENE CORALS, NEW GUINEA.

Plesiastrea. *Dachiardia.* *Stylophora.*

II.—The Ophiolithic Groups of the Ligurian Apennines.

II. Eastern Liguria.

By C. S. Du Riche Preller, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

General Features.

THE three principal ophiolithic groups of this region are those of Levanto, Monte Bianco, and Monte Penna, about midway between Spezia and Genoa, viz. north of Levanto, Sestri Levante, and Chiavari, at average altitudes of 300, 800, and 1,600 metres respectively. Like the Eocene ophiolithic group of Sestri Ponente and Isoverde, west of Genoa, they lie in the upper horizon of that formation, that is, in the fossiliferous (fucoids) albarese limestones and the argillaceous schists which rest on the Middle Eocene macigno sandstone as the lowest member of the Ligurian Eocene. The sedimentary and infolded ophiolithic groups consecutively aligned from the coast to the crest of the Apennines form a series of anticlines north to south, dipping west, with some transverse folds. The whole region is greatly contorted and brecciated; it is, moreover, profoundly eroded by torrents charged with calcium carbonate which has accelerated erosion and at the same time re-cemented breccia. Although the three groups are now separated, they are, together with the scattered islands north of the crest of the Apennines towards Piacenza in the Po Valley, only the remnants of an originally continuous formation of no less than 1,500 square kilometres or 600 square miles.

The principal ophiolithic rocks of the three groups are serpentine, euphodite, and diabase, with their varieties. The serpentine is both compact and schistose, and often of porphyric structure. There is no passage from serpentine to the other two rocks, but there are frequent transitions between the latter; serpentinous schist or pseudo-serpentine, often in transition to argillaceous schist, is also much in evidence. Associated rocks are the semi-crystalline schists known as *flaniti* and *diaspri*, viz. silico-calcareous, reddish and green schists, harder than limestone, indurated by taking up silica at the expense of lime, and containing radiolaria. Both, and notably the more highly indurated diaspri, form bands on the margin of ophiolithic rocks in proximity to calcareous masses.[1] It is a noteworthy feature that metalliferous deposits are found only in euphodite and diabase, never in serpentine, though often near the contact of the latter; again, manganese occurs, not in the ophiolithic rocks proper, but in the diaspri masses, though in the vicinity of the former.

I. The Levanto Group. (Figs. 1 and 5.)

This extends along the coast from Monterosso to Levanto, Bonassola, and Framura for about 10 kilometres, and inland about 20 kilometres to north of La Baracca on the high-road from Sestri Levante to Spezia. The precipitous, craggy outcrops along the coast are composed chiefly of greenish and dark reddish serpentine and of

[1] Indurated, silico-argillaceous schists are known as *galestri*, yellowish, red, or green in colour; *ardesia* are tegular, silico-argillaceous-calcareous schists; and *resinite* is a white or yellowish siliceous, semi-opaline variety.

euphodite alternating with argillaceous schist all more or less decomposed, except the euphodite with felspathic base and smaragdite of Bonassola, which, though it exhibits secondary minerals, is comparatively fresh.[1] The principal outcrops inland are exposed along the road from Levanto to La Baracca (600 m.), where the ophiolithic series may be conveniently studied in the numerous quarries of the beautiful and well-known "green marble of Levanto", largely used for ornamental purposes. It is essentially compact serpentine, greenish and rusty red, with clear white veins which are fissures filled with calcite. The rock passes to a more crushed and brecciated variety, re-cemented by calcium carbonate as ophicalce. Another variety is the so-called *ranochiaia* or frog-coloured, which in a greenish yellow groundmass exhibits fine, black, arborescent tissues of opacite. The compact serpentine also passes to schistose, fibrous, and steatitic, is often spheroidal, and, when it contains enstatite, diopside, bronzite, and notably diallage, is porphyric in structure. Along the same road serpentine often alternates with euphodite more or less altered, and with intermediate strips of pseudo-serpentine. The ophiolithic rocks are normally intercalated between argillaceous schists as the lower, and limestones as the upper strata, with occasional intervening claret-coloured diaspri. North of the Sestri and Spezia road occurs the cluster of serpentine and euphodite masses of Tavarone between Castiglione and Maissana, of Velva, Carro, Baracchino, and Matterana (Bracco), in all of which the euphodite is largely gneissiform and, notably north of La Baracca, forms a considerable area. Another interesting mass is that near Pignone, about 10 km. east of Levanto and the same distance north of Spezia, which constitutes, in the Eocene strata, a band of about 8 by 1 km. of serpentine and euphodite, like those of the Levanto group.[2] It runs north-west to south-east, parallel to the latter and to the coast towards the Cretaceous, Liassic, and Rhætian strata of the Porto Venere or western arm of Spezia Bay, and forms the link between the ophiolithic groups of Eastern Liguria and those 15 km. further east of Sarzana, Lunigiana, and Garfagnana in the Magra and upper Serchio Valleys along the northern margin of the Apuan Alps.

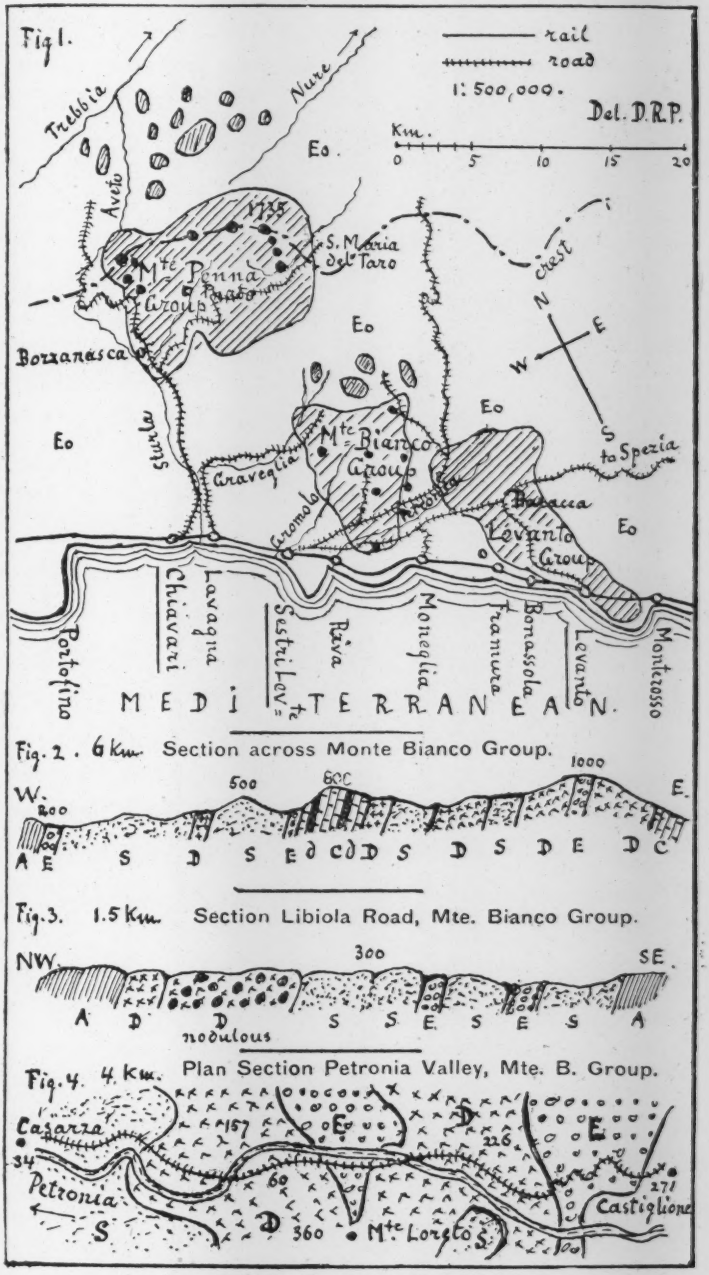
II. The Monte Bianco Group. (Figs. 1–4 and 6.)

This ophiolithic and remarkably metalliferous area is situated north-west of the Levanto group; its lower end, touching the Sestri and Spezia road near Bracco (448 m.), lies about 6 kilometres north of the former town. It covers about 10 by 5 kilometres, and is crossed north-east to south-west by the deeply eroded ravines of the Graveglia, Gromolo, and Petronia torrents in its northern, middle, and southern part respectively. It is traversed north to south by three more or less parallel ridges, viz. anticlinal folds dipping west, the highest

[1] Some of the rocks near Levanto were described by Professor Bonney in op. cit., Geol. Mag., 1879, p. 362 et seq.

[2] Specimens of the Pignone group were examined microscopically by Professor A. Cossa of Turin, who also gives analyses of the same in comparison with some of the similar Ligurian and Tuscan rocks (Boll. R. Com. geol., 1881, p. 246 et seq.).

Sketch Map of Ophiliothic Groups, Eastern Liguria



A = Arg. Schist; E = euphodite; D = Diabase;
S = Serpentine; C = Limestone; D = Diaspri.

Sketch Map of Ophiolithic Groups, Eastern Liguria.

Fig. 5. Levanto Group. Fig. 6. Monte Bianco Group.

Fig. 7. Monte Penna Group.

or eastern of which includes Mte. Porcile (1,249 m.), Zenone (1,072 m.), Alpe (1,096 m.), and Pù (1,007 m.), while the middle one comprises Mte. Bianco (876 m.), Rocca Grande (968 m.), Mte. Treggin (876 m.), and Mte. Loreto (360 m.), and the western descends to 400 and 300 m. altitude.

The ophiolithic rocks are infolded in the usual Eocene sedimentary strata, notably fine-grained, bluish-white, nodulous, and banded limestone, and argillaceous schists, frequently tilted almost vertically. Serpentines predominate more especially in the eastern, diabase and euphodite in the western and central part; their proportion may be roughly estimated as being 2/5, 2/5, and 1/5 respectively. The northern margin of the group is, between the ophiolithic rocks on one side and the calcareous rocks on the other, fringed by bands of claret-coloured diaspri up to one kilometre in width, which crop out on some of the highest points of the middle and eastern ridges such as Mte. Bianco, Rocca Grande, Mte. Treggin, Porcile, and Alpe. The principal roads leading from the coast up into the hills are those from Sestri to Casarza and Castiglione (271 m.) along the Petronia Valley in the southern, and from Lavagna along the Graveglia Valley to Nascio (390 m.) in the northern part of the area, as also the roads up the Gromolo Valley to the Libiola mine (380 m.), and from Casarza to Bargone in the centre of the area. The first of these more especially crosses in succession the serpentine, diabase, and euphodite masses in a natural section west to east of about 4 kilometres, along the Petronia Valley between Casarza and Castiglione. This section is very similar to a larger, parallel one across the widest and central part of the group from the Gromolo Valley to Rocca dell'Aquila, Rocca Grande, and Monte Zenone, cutting the three anticlinal folds and the synclines between them. These sections and another interesting one along the Libiola road, showing nodulous diabase, and euphodite veins in serpentine, are represented in Figs. 2, 3, and 4.[1] Throughout these sections the euphoditic masses more than the other rocks are greatly altered, and often decomposed; the contact with serpentine is always distinct, while euphodite and diabase constantly merge into each other.

The euphoditic and diabasic masses throughout the area contain considerable nodules of copper pyrites which are worked in a number of mines, some of whose approach-tunnels afford interesting exposures. One of these is notably the Libiola mine above the hamlet of that name and in the Gromola Valley on the western margin of the area at about 350 metres altitude, in a diabasic island of a serpentine mass. The green and reddish diabase here is not only compact but forms laccolitic aggregations in which nodules of pyrite are embedded and separated from the encasing rock by thin strips of white resinite. In another mine on the left of the Gromolo torrent nodulous euphodite appears encased in serpentine, which is completely altered to steatite. Manganese is found only in the diaspri bands, while serpentine throughout is devoid of metalliferous deposits, as previously stated, though they often appear in close proximity to it.

[1] These sections are deduced from L. Mazzuoli's in "Formazioni ofiolitiche della Riviera di Levante, Liguria": Boll. R. Com. geol., 1892, p. 2 et seq.

It was urged at one time as a remarkable phenomenon that in Eastern Liguria serpentine always appears superposed on euphodite and diabase, whereas in other parts of Italy, e.g. in Tuscany, the reverse is the case.[1] The former phenomenon is, however, apparent rather than real, being due not only to the effects of erosion which sometimes expose the outcrops at abnormal levels, but more especially to faults and inverted folds in connexion with the greatly disturbed stratigraphical condition of the whole region. Of this condition a striking example is afforded in the very centre of the area by Monte Treggin (870 m.), a sharply pointed, rugged peak, which is not only surrounded by chaotic masses of breccia and rock-débris, but is itself a confused agglomeration of the ophiolithic and sedimentary rocks of the area, strangely brecciated, crushed, intermixed, and contorted. This phenomenally disturbed condition extends from Mte. Treggin north to the serpentine mass of Mte. Bocco (1,027 m.), and south to the ophiolithic masses near Bargone and Mte. Loreto across the Bargonasco and Petronia Valleys; it constitutes, in fact, an eminently cataclastic zone which runs north to south midway of the area and also from La Baracca along the western margin of the Levanto group down to the coast near Bonassola.

III. The Monte Penna Group. (Figs. 1 and 7.)

This extensive ophiolithic area, the most northern of the three groups, lies north of Chiavari, whence Monte Penna, the highest point of the Ligurian Apennines (1,735 m.), forms a conspicuous object, distant about 25 kilometres. The group comprises a series of mountains disposed, on the crest of the Apennines, in a semicircle facing west and about 15 kilometres in length. In the centre of this semicircle, at 550 metres altitude, or nearly 1,200 metres below the crest, lies the village of Prato, one of a cluster of hamlets called Sopra la Croce, which possesses a mineral spring. About 900 metres above Prato, on Prato Molle, rises the Penna torrent, which, together with its numerous affluents, collects the drainage of the southern watershed of the Monte Penna group and discharges into the Sturla torrent at Borzonasca (160 m.). This village, about 15 kilometres from Chiavari, is the starting-point for the western and central part of the group, while the eastern part and Mte. Penna itself are also reached from S. Maria del Taro (700 m.). From west to east the group comprises Mte. Ajona, Cantomoro, Nero, Penna, Scaletta, Rocchetta, Pertusio, and Ghiffi, with the western lower spurs of Mte. Agugiaia, Campo Rondio, Mte. Bregaceto, and Mte. delle Lame, while Rocca Borzone forms a spur at the eastern extremity.

The ophiolithic rocks, chiefly composed of peridotite, lherzolite, serpentine, diabase, and their breccia, are, like those of the Levanto and Monte Bianco groups, infolded in Eocene argillaceous schists, limestone, and sandstone, and follow, with the latter, the same general direction north to south, dipping west, although the folds and alternations of both series are often so brecciated as to defy delimination. Between Borzonasca and Prato the sedimentary strata give place in

[1] See an earlier memoir by L. Mazzuoli & A. Issel, "Studi sulle masse ofiolitiche della Riviera di Levante": ibid., 1881, p. 313 et seq.

the upper part to brecciated limestone and diabase, whose repeated alternations are followed by a mass of diaspri wedged between diabasic breccia, and then by large masses of spheroidal diabase. From Prato, which lies in normal sedimentary strata, to Mte. Agugiaia (1,088 m.) the outcrops again disclose brecciated alternations with spheroidal and variolitic diabase, then a large mass of reddish bastitic peridotite which forms the cupola of Campo Rondio, and is surrounded by diabase and an outer fringe of argillaceous schist. Diabase is again in evidence on Mte. Bregaceto (1,171 m.) and extends to Mte. delle Lame (1,304 m.), which, though covered with plantation, exhibits that rock on its lower flanks.

From Mte. delle Lame the crest is reached on Mte. Ajona (1,692 m.), on whose comparatively broad and flat surface appears a very hard, dark-red, and rusty-coloured peridotitic rock in superposed layers like flagstones, with reticular ribs and wrinkles evidently due to atmospheric denudation. This rock, which is strongly magnetic and extends considerably north of the crest, obviously passes to serpentine on the southern flank, where serpentinous and limestone breccia appear infolded in argillaceous schist. The crest of Mte. Nero towards south-east of Mte. Ajona exhibits the same peridotitic rock passing to serpentine, and so does the remarkable outcrop of Pria Borgheise, a boss on Prato Molle (1,496 m.), below Mte. Nero, which was first noticed by Mazzuoli and, thanks to Professor Cossa's microscopic examination, was recognized as the first example of lherzolite in the Ligurian Apennines. East of Mte. Ajona rise Mte. Cantomoro and the peak of Mte. Penna, both composed of diabase, which also applies to Mte. Scaletta south-west of Mte. Penna. These three mountains obviously form a central mass of diabase between the peridotitic and serpentinous masses on the west and those of Mte. Pertusio on the east. Mte. Scaletta and Mte. Pertusio are separated by the argillaceous schist and limestone breccia of Mte. Rocchetta. The semicircular group is completed by Mte. Ghiffi, on whose northern flank appear limestone and breccia, the contact of these rocks and the serpentine of Mte. Pertusio being exposed in the saddle between the two mountains. On the descent from here by Rocca Borzone the hard diabasic breccia with associated diaspri appear again, being evidently connected with those already noticed above Prato. A notable feature of the Mte. Penna group is the absence of superficial outcrops of euphodite, though that rock probably occurs in places below the surface where the latter is covered with vegetation or detritus, in association with diabase and serpentine as it does in the other ophiolithic areas of Eastern Liguria. North of the Mte. Penna group, about a dozen ophiolithic, chiefly serpentinous, islands crop out in the Trebbia, Aveto, and Nure Valleys, near Bobbio, S. Stefano, and Ferriere respectively, towards Piacenza in the Po Valley; they are obviously a continuation of the Ligurian groups.[1] The diabasic masses

[1] L. Mazzuoli, "Formazione ofiolitica nella Valle del Penna": Boll. R. Com. geol., 1884, p. 384 et seq. A. Cossa, "Intorno ad alcune roccie della Valle del Penna nell'Apennino ligure": Rendiconti R. Accad. Lincei, Roma, 1886, pp. 502 and 643 et seq. Professor Cossa, of Turin, also first examined

of Mte. Cantomoro, Penna, and Scaletta extend south-east, towards Varese-Ligure, to Mte. Quatese, Cavallone, Setterano, and Carignone, all at about 1,300 metres altitude, in three more or less parallel zones with intervening strata of argillaceous schist containing abundant lenticular intercalations of diabasic breccia, of which extensive agglomerations also appear on the northern flanks of Mte. Penna. The diabasic zones obviously represent original submarine lava streams flowing in the planes of the plastic sedimentary strata in which the débris became infolded and cemented to breccia.

Conclusion.

The phenomena presented by the ophiolithic and sedimentary groups of Eastern Liguria are substantially the same as those of the Triassic Voltri and the Sestri and Isoverde Eocene groups west of Genoa. Both regions afford striking evidence of intense folding, crushing, contortion, and brecciation which the sedimentary and the ophiolithic rocks of submarine eruptive origin during their contemporaneous uprise and subsequent settling experienced alike. There is no tangible evidence of these groups being transported areas, while everything points to their emergence and location in situ.[1] The effects of repeated earth-movements, including those of a seismic character, are strikingly evidenced by the frequently cataclastic condition of the Ligurian littoral from the coast to the crest of the Apennines, and the compression of the region during its uprise and settlement must have been all the greater considering that it lies in the contracted semicircular curve of the Gulf of Genoa.

III.—On the Classification of the Terebratellidæ.

By J. Allan Thomson, M.A., D.Sc., F.G.S., Director of the Dominion Museum, Wellington, New Zealand.

Introduction.

The observations presented by Mr. J. Wilfrid Jackson (1916)[2] on my paper on "Brachiopod Morphology", published in this Magazine in 1915, are very welcome as furnishing many important details omitted by Davidson and other writers in the description of species. The error into which I fell as regards the types of folding of *Dallina* and *Dallinella* illustrates the danger of relying on figures when specimens are not available, but it was worth while making such an error when the correction of it brought forward so many useful observations on other points, particularly on the prevalence of

microscopically some of the ophiolithic rocks on the north of the Apennines: "Sopra alcune roccie serpentinose dell'Apennino Bobbiese," Boll. R. Com. geol., 1881, p. 58 et seq.; also D. Zaccagna, Relazione, 1902; ibid., 1903, p. 39.

[1] Further east towards Spezia the Mesozoic and Tertiary sedimentary strata exhibit an abnormal superposition which has always been regarded as an extensive inverted fold, but may be the effect of an overthrust. In the ophiolithic areas of Eastern Liguria, on the other hand, the Eocene sedimentary sequence is normal.

[2] References are given in the list of papers at the end of this article, and are indicated in the text by the author's name and date.

dental plates in the Dallininæ and the relationships of *Mühlfeldtia*. These observations pave the way for a further advance in the natural or genetic grouping of species and genera. At the same time, while admitting that *Dallina* is ventrally biplicate, I am not disposed to agree with Mr. Jackson that the folding is exactly comparable to the ventral biplication exhibited in some species of *Magellania*, but probably arose in a different way. I refrain from a further statement on this point, as I understand that Mr. S. S. Buckman is discussing the subject of types of folding fully in his forthcoming memoir on the Jurassic Brachiopods of Burma. In what follows I shall have again, through lack of specimens in Colonial museums, to rely on figures to some extent, and may possibly again err from this cause, and if so hope the correction will be applied as promptly and informatively as in the former case.

Primary Divisions of the Terebratellidæ.

Beecher, in 1895, recognized three subfamilies within the Terebratellidæ, distinguished by loop characters and development, viz.: the Megathyrinæ, the Dallininæ, and the Magellaninæ. In 1897 Schuchert included besides these three also the Devonian Tropidoleptinæ, but in 1913 he relegated this subfamily to the Strophomenidæ, with the other members of which it agrees more nearly in geological age, and retained in the Terebratellidæ only the three subfamilies adopted by Beecher, whose epoch-making classification has thus stood the test of time for twenty-one years.

Certain minor modifications of Beecher's statement of the order of loop development in the higher subfamilies of the Dallininæ and Magellaninæ have become necessary owing to the re-naming and closer definition of some of the genera on which he based his terms. The following table shows the former and the revised nomenclature :—

Stages of Loop Development in Terebratellids.

Dallininæ.		Magellaninæ.	
Beecher, 1895.	Revised Nomenclature.	Beecher, 1895.	Revised Nomenclature.
		Bouchardiform }	Premagadiniform.
Platidiform.	Platidiform.	Megerliniform }	
Ismeniform.	Ismeniform.	Magadiform.	Magadiniform.
Mühlfeldtiform.	Frenuliniform.	Magaselliform.	Magelliform.
Terebrataliform.	Terebrataliform.	Terebratelliform.	Terebratelliform.
Dalliniform.	Dalliniform.	Magellaniform.	Magellaniform.

The reasons for an alteration of the terms applied to early stages of *Terebratella* and *Magellania* have been fully explained in former papers (Thomson, 1915, Nos. 2 and 3). The substitution of 'Frenuliniform' for 'Mühlfeldtiform' has been proposed by Jackson (1916) on the ground that *Mühlfeldtia* belongs to the Magellaninæ and not to the Dallininæ. In any case 'Frenuliniform' is the

preferable term, since Beecher had really *Frenulina sanguinolenta*[1] in mind when he spoke of *Mühlfeldtia*, for although he mentioned *M. truncata* he used in his illustrations *M. sanguinea* = *Frenulina sanguinolenta*.

The so-called 'Platidiform' stage of the loop in the Dallininæ is not strictly comparable to the brachidium of *Platidia*, as is shown below, and does not appear to be represented in the adult brachidium of any known genus, but it can hardly be doubted that a genus with such characters will one day be found.

Jackson's reasons for removing *Mühlfeldtia truncata* from the Dallininæ and placing it in the Magellaninæ are the absence of dental plates, the resemblance of one of its early loop stages to an early loop stage of *Terebratella dorsata*, and the appearance of the secondary loop before the appearance of the primary lamellæ. Deslongchamps showed clearly in 1884 that the young loop stages of *Megerlia truncata* (= *Mühlfeldtia truncata*) form a close parallel with the adult brachidia of *Kraussina* and *Megerlina*, and it is somewhat remarkable that Beecher overlooked this resemblance and did not suspect the generic distinctness of "*Mühlfeldtia truncata*" and "*Mühlfeldtia sanguinea*".

Differences between Dalliniform and Magellaniform Ontogeny.

Before discussing whether *Mühlfeldtia* may be admitted into the Magellaninæ, it is desirable to analyse the difference in loop development between that family and the Dallininæ. Beecher pointed out that in the lower genera the median septum is generally low in the Dallininæ and projecting above the loop in the Magellaninæ. In *Bouchardia*, *Magas*, and *Magadina* it almost touches the opposite valve. In the young growth stages of the higher genera this difference between the subfamilies is not so marked, for the early platidiform stages of *Macandrevia* show a high septum. It remains true, however, that a high septum persists longer in the Magellaninæ than in the Dallininæ. There is also a slight difference in the form of the septum, which is more elongate and board-like in the Magellaninæ.

In both subfamilies the secondary part of the loop appears first as a small hood[2] on the septum, with the opening upwards and forwards. In the Magellaninæ this hood is confined to the posterior, slightly lower, end of the septum, but in the Dallininæ it projects further forwards. At this stage there is an important difference, emphasized by Jackson, viz., that in the Dallininæ the primary loop is complete from the crural bases to the septum, whereas in the Magellaninæ it is imperfect. It does not appear to be yet known whether the

[1] *Anomia sanguinea*, Chemnitz, being polynomial, Gmelin's name must be used for this species as Dall has suggested. Beecher's illustrations are based on those of Deslongchamps (1884), who referred to it as *Terebratella sanguinea*. It is, of course, a different species from *Terebratella sanguinea*, Leach, which was known at that date as *Terebratella cruenta*.

[2] The earliest stage of *Terebratella dorsata* described by Fischer and Oehlert (1892), which shows the secondary loop, has a ring on the septum, but I have detected an earlier stage with a hood in *T. rubicunda* (Thomson, 1915, No. 3).

growth of the primary lamellæ in the Dallininæ commences both from the septum and the crura, as is the case in the Magellaninæ, or from the crura only. In the Magellaninæ the completion of the primary lamellæ is attained only after the hood has developed into a ring, and on its completion the Magadiniform stage is reached. In this stage the primary lamellæ and the ends of the ring are separately attached to the septum, and at a considerable vertical distance apart. In *Platidia*, as figured by Fischer & Oehlert (1891), the same is true, but in the earliest known Platidiform stages of *Macandrevia* and *Dallina* the attachment of the primary lamellæ is very oblique, and the anterior part unites with the end of the hood. A similar oblique attachment and union is not attained in *Terebratella* till a later stage, the Magelliform, when the ring has attained a considerable size and is widely open.

Some similarity exists between late Platidiform and Ismeniform stages of *Macandrevia* and *Dallina* on the one hand and early Magelliform stages of *Terebratella* on the other. In all of these the primary lamellæ are complete, and run forward obliquely up the septum to unite with a ring above. The differences are that in the Platidiform and Ismeniform stages the ring is not so large nor so widely open, while its lower ends project forwards into two divergent points, whereas in *Magella* and in Magelliform stages the lower ends are more or less rounded.

The chief difference in later stages is that in the Dallininæ lacunæ open on the lower sides of the ring and so produce a Frenuliniform stage which has no counterpart in the ontogeny of *Terebratella* or *Magellania*.

Mühlfeldtia and its Allies.

Mühlfeldtia truncata differs in its ontogeny from members of Dallininæ in that the secondary part of the loop appears as a ring before the primary lamellæ appear. Furthermore, as in the Magellaninæ the primary lamellæ grow from each end to unite in the middle. There appear, however, to be other features in which differences from the Magellaninæ exist, and some resemblance to Dalliniform ontogeny may be traced. The high board-like septum of the early stages of the Magellaninæ does not appear to exist so far as one may judge from the figures of Deslongchamps (1884) and Fischer & Oehlert (1891). Certainly in *Kraussina* and *Megerlina* the septum is quite low. The ring above the septum in the earliest known stages of *Mühlfeldtia* is different in shape and position from the ring in pre-Magadiniform and Magadiniform stages of *Terebratella*. It lies further forward on the septum, and the lower sides exhibit forward extensions not shown in the early stages of *Terebratella*. At a later stage in *M. truncata*, and in the adult brachidium of *Megerlina Lamarckiana*, small points which represent the anterior beginnings of the primary lamellæ appear, not on the septum, but on the lower outer sides of the ring, if Deslongchamps' figures may be trusted. This difference both from the Dallininæ and the Magellaninæ appears sufficiently fundamental to necessitate the recognition of a subfamily to include *Mühlfeldtia*, *Megerlina*, and *Kraussina*. Before such a step is taken,

however, it is desirable that a further study of the young stages of *Mühlfeldtia* should be made. Had Deslongchamps presented side views of the specimens he figured, all ambiguity would have been avoided.

In its further development *M. truncata* diverges greatly from the Terebratelliform ontogenetic series. Apparently what in the adult loop resembles the jugal band of a *Terebratella* is really the original bottom part of the primitive ring, little modified except in size. The anterior extensions of the ring become greatly enlarged, and with them the primary lamellæ increase in length, although remaining attached to the lower sides of the ring at their point of origin. Neither Davidson, Deslongchamps (1884), nor Fischer & Oehlert (1891) show in their figures any sign of lacunæ such as occur in *Frenulina*, but in a specimen from the Mediterranean in the Dominion Museum, Wellington, they exist as narrow slits separating for some distance the anterior extensions of the primary lamellæ from the anterior extensions of the ring.

There is another genus which by an anterior extension of the secondary part of the loop prevents some resemblance to *Mühlfeldtia*, viz. *Campages*, Hedley (1905), which occurs on the south and east coast of Australia. In the type species, *C. furcifera*, Hedley, there is also a slight development of lateral lacunæ, but these do not appear to be present in the only other known species, *C. jaffaensis* (Blochmann).[1] Through the kindness of Dr. J. C. Verco, of Adelaide, I have been able to examine a small series of the young of the latter species. In these the typical high septum of the Magadiniform and pre-Magadiniform stages of *Terebratella* is seen, and up to the Magadiniform stage there is no marked difference from the young of *Terebratella* except that the ribbon of the ring is broader and extends further forward. The later stages are not well displayed by the series, but it is evident, from the occurrence of a Magadiniform stage with widely separate attachment of the primary lamellæ and of the ring on a high septum, that *Campages* is not a close ally of *Mühlfeldtia* but an undoubted member of the Magellaninæ, with a loop representing a specialized development of the Magelliform stage.

There are two other species that should be considered in this connexion, viz. *Megerlia Willemoesi*, Davidson, and *Terebratella furculifera*, Tate. The former is a recent species obtained by the *Challenger* Expedition off Twofold Bay, New South Wales, and has a loop resembling that of an early Terebratelliform stage of *Terebratella*, except that the reflected part of the loop is attached to the septum by two descending lamellæ, thus enclosing a triangular space. In *T. furculifera*, Tate, an Australian Tertiary fossil, the same kind of connexion with the septum occurs, but the brachidium appears to be rather more advanced, and comparable to a late Terebratelliform stage. These two species occur in the same region and are thus probably related. Their loop characters are quite distinct from those

[1] Originally described by Blochmann (1910) as *Magasella jaffaensis* and ascribed to *Campages* by Hedley in 1911. Hedley also considered *Magellania Joubini*, Blochmann, a species of *Campages*, but this species appears to be correctly placed under *Magellania*.

of *Laqueus* or any other known genus, and justify the erection of a new genus.

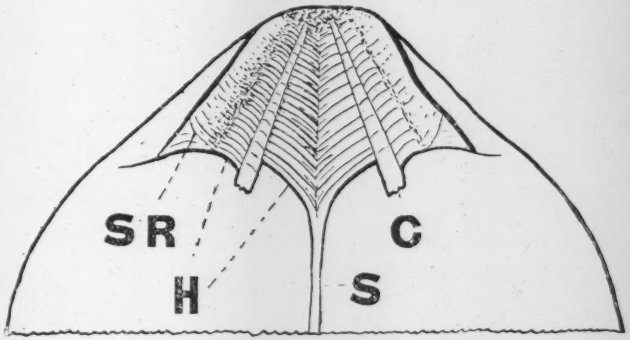
ALDINGIA, gen. nov.[1]

Genotype *Terebratella furculifera*, Tate.

Until the growth stages of *Aldingia* are known, the subfamily of the Terebratellidæ to which it belongs cannot be determined, but it appears not unlikely that it passes through a Mühlfeldtiform stage in its ontogeny, and that the descending lamellæ uniting on the septum are comparable to the sides of the primitive ring in *Mühlfeldtia*.

GENETIC STOCKS IN THE MAGELLANINÆ AND DALLININÆ.

In a former paper (1916, No. 2) I have endeavoured to show that Magellaniform loops have been produced by parallel evolution in at least three distinct stocks, each characterized by its own type of cardinalia[2] and beak characters. There are, doubtless, many other stocks equally worthy of generic recognition in the Magellaninæ, but the evidence for their separate attainment of the Magellaniform loop is not yet forthcoming.



Dallina floridana, Pourtales. Anterior-ventral view of cardinalia of dorsal valve. SR. socket ridge ; H. hinge-plates ; C. crural bases ; S. septum. There is no cardinal process. Enlarged about 2½ nat. size.

Thanks to Jackson's valuable observations we are now able to recognize similar evolutionary stocks in recent Dallininæ. Thus *Terebratalia* and *Thomsonia* are shown both to possess hinge-plates and a similar type of cardinalia differing markedly from that in *Dallina* and *Macandrevia*. As the type of the folding and the beak characters are also similar in *Thomsonia* and *Terebratalia*, these genera doubtless form one evolutionary stock.

Jackson states that *Dallina* possesses typically Magellaniform cardinalia, but it appears useful to draw a distinction. The only

[1] Named from Aldinga, South Australia, a notable locality for Tertiary Brachiopods.

[2] This term I intended as a (Latin) neuter plural, but in my former paper it was used as a singular noun, and I had not an opportunity to revise the proofs.

species to which I have access, *Dallina floridana*,[1] possesses hinge-plates excavate anteriorly, under which the septum reaches right to the umbo as in *Magellania*, but there is this difference, that in *Dallina floridana* the crural bases are not closely applied to the inner sides of the socket ridges, as is the case in *Magellania flavescens*, but run independently from the umbo, so that each hinge-plate is separable into two parts, one between the socket ridge and the crural base, the other between the crural base and the middle line over the septum. It is this distinction, so clearly marked in this species, that led me to revive the term of "socket ridge" for the "buttress" forming the inner wall of the dental sockets. In most types of cardinalia the crural bases are firmly united with the inner sides of the socket ridges and cannot be separately distinguished, although sometimes, as in *Neothyris lenticularis*, even when the two are firmly united laterally a line of demarcation can be more or less traced on the upper surface. Should *Dallina septigera* possess the same features as *D. floridana*, the type of cardinalia above described may be termed the Dalliniform type. In looking for a forerunner of *Dallina* with Terebratelliform loop, one would require as an essential a Dalliniform type of cardinalia. This may exist in *Terebratula spitzbergenensis*, Davidson, which Jackson groups with *Dallina septigera* and *D. floridana* in type of cardinalia, but these species appear to have distinct beak characters. In the terminology of Buckman (1916) *Dallina* had a mesothyrid foramen, while *Terebratula spitzbergenensis* appears to have, according to Davidson's figures, a submesothyrid foramen. More probably the forerunner of *Dallina* looked for will be found in *Terebratella Mariæ*, A. Adams, or in the Italian Pliocene form *T. septata*, Philippi.

In my previous paper (1916, No. 1) I suggested that the forerunner of *Macandrevia* with Terebratelliform loop might be looked for in *Terebratula frontalis*, Middendorff, but refrained from creating a genus for its reception because of ignorance of its hinge-characters. Jackson states that it possesses somewhat obscure dental plates much as in *Terebratalia*, and that its loop development and cardinalia suggest relationship with the Terebrataliform stage of *Macandrevia cranium*. I have now secured a specimen of this species and find some further points of agreement with *Macandrevia*, but also some differences. Jackson, in describing the pedicle collar, mentions that it is never developed in the higher long-looped forms, in which *Macandrevia* is included, but stated that in some of these "there is occasionally a thickening in the umbo around the foramen assimilating a pedicle collar, but it is fused to the shell and never free anteriorly". In *Macandrevia* such a plate is well developed in old shells, and extends as far forwards as the dental plates, with the base of which it is firmly fused, giving the appearance that the dental plates and the pedicle collar form a single structure free laterally from the walls of the shell but closely applied to the floor. I have observed this feature most clearly in a new species of *Macandrevia* from the

[1] Two specimens presented to the Dominion Museum, Wellington, by the United States Deep-sea Dredging Expedition off the Coast of Mexico, 1869.

Antarctic, but it also exists in *M. cranium*.[1] It is thus described by Dall (1895) in *M. americana*: "teeth strong, short, supported each by a strong buttress with a recess behind it, and in old specimens with a smooth deposit of callus on the surface of the valve between the two buttresses." This type of dental plates, supported by a deposit of callus on the floor of the valve, differs from that of *Hemithyris*, and may be termed the Macandrevian type. *Hemithyris* has a true but short pedicle collar, with which the deposit of callus in *Macandrevia* does not appear to be homologous. The Macandrevian type of dental plates is also found in *Terebratella frontalis*.

The beak characters of *Macandrevia* are of an unusual type. The pedicle opening consists of two parts—a rounded foramen, which is permesothyrid in position,[2] opening into an open delthyrium. In the usual course of events in Terebratellids, when the foramen has attained the mesothyrid position, the delthyrium has become closed by deltidial plates. In *Terebratula frontalis* the movement of the foramen ventralwards does not appear to have gone quite so far, but the relation to the delthyrium is the same.

The cardinalia of *Macandrevia* are also of an unusual type. The crural bases are fused on their outer sides to the socket ridges as in *Magellania*, and from their inner sides two hinge-plates, excavate anteriorly, descend obliquely to the floor of the valve, and becoming fused with this unite in the middle line of the valve. In the Antarctic species above-mentioned, from which this description is drawn, these hinge-plates do not extend forward beyond the crural processes, and there is a raised thread-like line occupying the position of the median septum. In *Macandrevia cranium*, Davidson (1886) states that there is no defined cardinal process or median septum, but that two deviating septa commence under the umbo and extend to a little more than one-fourth the length of the valve. These so-called septa are apparently anterior prolongations of hinge-plates similar to those described above. It is desirable that the ontogeny of the Macandreviform type of hinge-plates should be worked out. It bears some resemblance to that of early stages of *Terebratella rubicunda*, but it seems not impossible that it is a further development from a Magellaniform type.

In *Terebratula frontalis* a different type of cardinalia exists. There is a small median septum situated in front of the middle of the valve, and from it a raised thread-like line extends back to the cardinalia as in *Macandrevia*. The crural bases cannot be traced in the cardinalia with certainty. The crura spring from the anterior inner corners of strong socket ridges, between which there is a mass of shell substance overhanging in front and embayed nearly to the umbo. The outer edges of this overhanging mass are raised into ridges, and perhaps mark the crural bases, and between these ridges and the socket ridges there are well-marked depressions on the mass. On the back of the mass is superposed a small transverse cardinal process.

[1] It is figured, but not described, by Fischer & Oehlert (1891, pl. v, fig. 10 f.).

[2] The beak ridges are poorly defined, and it is difficult to be quite certain of their position. The foramen is certainly not of the submesothyrid type, into which most Terebratellids with lateral deltidial plates fall.

Terebratula frontalis cannot be placed in *Terebratalia* and requires a new genus for its reception, for which I propose:

DIESTOTHYRIS, gen. nov.

Genotype *Terebratula frontalis*, Middendorff.

Diestothyris presents many of the characters that are to be expected in a forerunner of *Macandrevia*, and differs only in its type of cardinalia. It may be provisionally regarded as belonging to the same stock as *Macandrevia*, although not in the direct line of descent of that genus.

The above discussion shows that by taking into consideration characters of beak, hinge-teeth, and cardinalia in addition to loop characters, much may be done to arrange the recent species of the Dallininæ into genetic stocks. The discussion is by no means exhaustive, and has not included the lower genera, for which a better knowledge of the Tertiary fossils of the Northern Hemisphere is desirable.

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IV.—On the Age of the Crystalline Schists in the Piedmontese and other parts of the Alpine Chain.

By Professor T. G. BONNEY, Sc.D., F.R.S.

DR. PRELLER'S recent contributions to this Magazine on the geology of the Piedmontese Alps prove that (1) Italian authorities have expressed widely different opinions on this subject, and (2) some of them have maintained sundry Alpine gneisses and crystalline schists to be Palæozoic or Mesozoic (often Permian or Trias) in age. I infer from these contributions that he is well acquainted with the physical geography of this region, but fail to find in them any signs of either microscopic study or independent petrological work. As these have led me in several cases to very different results, I shall venture to put them on record as briefly as possible. In the course of thirty-five visits I have wandered over the peaks and valleys of the Alps from the southern border of the Cottians to the Salzkammergut, paying at first much more attention to physical than petrological questions. But in 1869, when beginning to lecture on geology, I found not only (as I was already aware) that my knowledge of rocks was scanty, but also that on this subject very little trust could be given to much that had been written. So I tried, as best I could, to teach myself.[1] With this intention I visited many places of petrological interest in our own country and on the Continent, forming (partly by purchase) a considerable collection of rock specimens and slices. Circumstances soon directed my attention to the gneisses and crystalline schists, and from 1872 I paid more and more attention to them in my Alpine journeys, of which this was the thirteenth. In 1885 (my twenty-first journey) I began endeavouring to obtain clearer ideas about their succession, history, and relation to the ordinary stratified rocks, by running sections, sometimes up to, sometimes across the watershed of the chain, going in that year from the Lake of Lucerne to the Lago Maggiore and returning across the Great St. Bernard. In 1887 I made two other complete sections, one from Grenoble to Pinerolo across Dauphiné, the other across the Tyrol well to the east of the Brenner Pass, and since that date, till the last and thirty-fifth in 1911, each journey has kept petrological questions well in view. On looking over a list of my geological papers I see that about thirty deal with Alpine petrology, and may add that one result of these journeys has been a collection

[1] Sorby, the "Father of Microscopic Petrography", had not published much on that subject before this date, David Forbes still less, and Samuel Allport was only beginning. The ordinary textbooks of geology were either of no value or misleading.

of rock specimens, which fills about thirty drawers, and of about 500 slices for the microscope.[1]

Thus, as my opinions have not been formed without the expenditure of time and trouble, I hope to be forgiven for expressing them with some confidence. Experience had already taught me, before beginning this work, that even accepted authorities might prove to be misleading, so I consulted, as is my usual practice, the "literature of the subject" only so far as to ascertain the localities where the most conclusive evidence on the points at issue was likely to be found. For the sake of brevity I shall restrict myself to two questions, which seem to me the most important of those raised by Dr. Preller: (1) the origin of the pietre verdi, including their relation to the associated rocks, and (2) whether certain Alpine gneisses and crystalline schists are rightly regarded as Palæozoic or early Mesozoic in age.

The pietre verdi, according to the classification adopted by Dr. Preller (see p. 160 of this volume), comprise, in addition to the hornblendic and chloritic schists which the name commonly covers, dolerites, diabases, and gabbros with all their varieties, lherzolites and serpentines, and even porphyrites. This classification, in my opinion, is open to the fundamental objection that it includes, with the pietre verdi (a series of rocks which, whatever may be their origin, have much in common), a number of others which, though to some extent related to them in mineral and chemical composition, can often be proved to be intrusions of later date. Probably this is always the case, but in a highly folded region we cannot obtain such clear evidence of it as in one which is comparatively undisturbed. Still, in many cases, we cannot doubt the intrusive character of certain dioritic rocks, and of many masses of gabbro and serpentine (altered peridotite), and we lose rather than gain in clearness of view by including these among the pietre verdi, instead of separating them as is done on most of the large-scale Alpine maps, such as those of the Swiss Geological Survey. The green schists—grüner schiefer or schistes vertes—of these maps, wherever I have seen them from the Viso to the Glockner, have much in common. In the field they generally exhibit a more or less 'slabby' aspect, and a fine-grained, schistose structure, being often well foliated and sometimes showing mineral banding. The microscope proves them to consist (in variable proportions) of hornblende (sometimes glaucophane), chlorites, felspars (a secondary albite often being rather conspicuous), iron-oxides, and perhaps quartz. They are not seldom distinctly cut[2] by masses of serpentine (altered peridotites) and gabbros. The latter are occasionally very fresh, but more often the felspar is replaced by 'saussurite' and the augite or diallage by hornblende—the well-known smaragdite-euphotide[3] of the Saas-thal being the most remarkable variety. For some years I inclined to regard the grüner schiefer proper as being originally volcanic rocks—basaltic tuffs and

[1] Both these collections have been given to the University of Cambridge, and are in the Sedgwick Museum.

[2] As, of course, certain apparently older gneisses and schists may be.

[3] As this term, proposed by Delesse, has for long been familiar to English geologists, I do not see why Dr. Preller should call it euphodite (p. 161).

lava-flows—but found in process of work that there was generally an abrupt boundary between them and the associated micaceous schists. Only one section above Windisch Matrei[1] suggested a passage from the one to the other, and I should like to re-examine this as I might have overlooked slight thrust faults. But in not a few places[2] one can trace the transformation of clearly intrusive diabases into quite ordinary green schists.

The above-mentioned green schists are sometimes intrusive into certain varieties of gneiss and mica-schist of dubious origin, sometimes into the great group of crystalline schists, obviously metamorphosed sediments, which exhibit almost every gradation from schists consisting largely of mica into quartz-schists on the one hand and (through calc-mica-schists) into saccharoidal marbles on the other. The serpentines can be found intrusive into the green schists; the gabbro into the serpentines;[3] occasionally also an aplitic granite cuts the green schists, but I do not know its relation to the other two intrusives. Thus, though all these rocks (except the granite) are basic and more or less green in colour, I prefer to follow the Swiss geological maps in distinguishing as schistes vertes the pressure-modified diabases, and grouping them (though only provisionally) with the above-mentioned calc-mica and associated schists.

Since I began to pay special attention to the petrology of the Alps I have not seen much of the dioritic belt which extends from near Ivrea by Biella and Andorna to the Val Sesia, near Varallo; still, I have come across it two or three times, enough to refresh my memory and give me a general idea of its characters. Its members may very well have been drawn from the same source as the schistes vertes and their associates, but they have probably consolidated under different (deeper-seated) conditions, and may thus be conveniently distinguished from them. As, however, this question does not seem to me to have any very direct bearing on the nature and origin of the schistes vertes, I shall venture to pass by it, merely remarking that I greatly doubt whether the porphyrite north of Biella can be included in the dioritic belt. That rock, which is more extensively developed in the neighbourhood of the Lago Maggiore, seems to me the western-most extension of the great zone of porphyrites, Permian in age, which are so largely developed near and to the east of the Adige in its course from Meran to Trent.

The second and most important point is the geological age of the schistes vertes and certain other schists associated with them. This, according to the authorities followed by Dr. Preller, is from Permo-Carboniferous to Trias; one division of the pietre verdi with certain mica-schists and minute gneisses belonging to the former, the other division with the calc-schists and crystalline limestones, to the Lias–Trias.[4] Much apparent, but very little real, evidence is cited to support these determinations, and I do not hesitate to say, after

[1] Q.J.G.S., 1889, pp. 87, 88, 108.

[2] Id., 1893, pp. 94–103; 1894, pp. 279–84; 1903, pp. 55–6.

[3] Gabbro intrusive into serpentine is, of course, a very common thing. I may add that locally the schistes vertes are cut by eclogites.

[4] See p. 307.

having carefully studied not a few of the sections on which it rests, that they prove either nothing or the contrary.

Time will be saved in discussing these sections by making two statements: First that I have never succeeded in finding a shale of later Palæozoic or Mesozoic age converted by dynamometamorphic action into anything more than a phyllite—meaning thereby a slaty rock, which retains many traces of a sedimentary origin and in which the authigenous mica, though very abundant, can only be distinguished on microscopic examination, while that mineral in the ordinary crystalline schists of the Alps is much larger and is easily seen with the unaided eye. But a minute mica, like that of a phyllite though generally a little larger, may appear when a schist, gneiss, or granite has been crushed, and, besides this, the original mica may be reduced to small fragments. In such case the two schistose rocks may seem to be identical, but the difficulty of distinguishing them is restricted to a very narrow zone.[1]

The other point is that in a region much affected by folding and thrust-faulting the apparent succession of a series of rocks is not only without chronological value but may be actually misleading. It has had this effect on the authorities in whom Dr. Preller trusts, as I will endeavour to show as briefly as possible. His first paper describes the "Permian formation in the Alps of Piémont, Dauphiné, and Savoy", and I happen to be acquainted with some of the sections there cited, as, for instance, those between Bourg d'Oisans and Briançon and those to the south of the Mont Blanc range. In regard to the former I cannot venture to say how much of the great zone of non-crystalline rocks between Argentière and Moutiers is Permian (the Carte Géologique de la France makes the whole Upper Carboniferous, with a little overlying Lower Trias), but the two sharp infolds of the former on either side of Freney on the western side of the Lautaret pass are perfectly distinct from the enclosing gneiss, and ordinary Liassic strata rest upon both it and their denuded edges; overlying the former to beyond the Col du Lautaret, at elevations ranging from about 5,000 feet to 11,000 feet above the sea. Over this considerable area Permian and Trias are either absent or inconspicuous, at any rate till we come towards Briançon. As, however, I maintain that none of the stratified rock in this zone, whether later Palæozoic or earlier Mesozoic (which I have also examined in two or three places further north), is more metamorphosed than many grits and slates in Britain of the same geologic age, and that the Jurassic limestones do not differ appreciably from those in other parts of the Alps, I regard the exact geological position of the aforesaid deposits as unimportant. This, at least, is certain, that the Alpine rocks were affected by great earth-movements in both pre-Carboniferous and pre-Triassic times, and that the latter system was deposited on a very irregular surface, for in some places it is missing, in others it appears as that peculiar calcareous material called rauchwacké (often with gypsum), and in others as a group of ordinary stratified rocks, often limestones or dolomites.

[1] Q.J.G.S., 1884, pp. 4, 5, 21; 1889, p. 92, and remarks on rocks of the pietre verdi type at p. 98.

I will now notice a few sections which have been repeatedly quoted as proving the later Palæozoic or earlier Mesozoic age of true crystalline schists.[1]

1. In 1881 I was informed by a Swiss Professor of Geology that the well-known conglomerate of Carboniferous age in the Valorsine near Vernayaz exhibited partial metamorphism, mica scales, large enough to be seen with the unaided eye, having been developed in situ. After visiting the sections and examining the rocks under the microscope I had no doubt that the mica was derivative, like the fragments of gneiss, etc.[2]

2. Some foreign geologists have claimed the crystalline schists on the mountains near Zermatt, on either side of that branch of the Vispthal, with their prolongation eastward to the neighbourhood of Saas, as metamorphosed rocks of early Mesozoic age. The only evidence that I have been able to find for this identification is that here and there a little strip of ordinary rauchwacké (Trias) is nipped in among normal crystalline schists, which seems to me, as will be more fully shown in the next instance, strongly adverse to that conclusion.

3. The Val Canaria and Val Piora sections.—Here we find a group of mica-schists, often calcareous and sometimes passing into marbles, apparently infolded in rauchwacké, the most impressive section occurring in a ravine on the right bank of the Val Canaria. But I have shown this to be an impossible interpretation, if only from the fact that the rauchwacké contains abundantly fragments of the schists which are supposed to overlie it.[3] We obtain similar evidence on the upper part of the Lukmanier Pass some seven miles to the E.N.E., as well as at a rather greater distance to the W.S.W. between the Nufenen Stock and the Gries Pass.[4]

4. Another group of sections has been supposed to prove that certain staurolite and black-garnet schists (well developed near the Lago di Ritom) pass into schists in which these minerals (authigenous) occur with fairly well preserved belemnites and ossicles of crinoids. This assertion can be tested in sections on Scopi to the east of the Lukmanier Pass, between All'Acqua and the Nufenen Pass, and on the northern ascent to the Gries Pass.[5] In some cases the garnet-bearing mica-schist is parted by a little rauchwacké, from the fossiliferous schist (supposed), but in others the two are in sequence. The occurrence of fossils in the latter is indubitable, but the minerals claimed as garnets and staurolites are only secondary hydrous minerals, too impure for precise identification, and their matrix is not a true schist. In fact, these sections prove nothing more than

[1] The stock instance of gneisses and Jurassic limestones on the northern crags of the Jungfrau is now abandoned, so it needs no discussion.

[2] Geol. Mag., 1883, p. 507.

[3] See Q.J.G.S., 1890, pp. 199–211; 1894, pp. 297–300. There are four marked varieties of these schists, three of which I have found in the rauchwacké and the fourth at the base of the Lias near the Lukmanier Pass, where this rock rests directly on that particular schist.

[4] Q.J.G.S., 1893, pp. 90–1.

[5] Q.J.G.S., 1890, pp. 213–21; 1893, pp. 90–1.

remarkable ignorance on the part of certain foreign geologists.[1] Want of space prevents me from discussing in detail the petrological statements on pp. 158–62 of this volume, so that I must be content with saying that, when work in the field is checked by study with the microscope, the lessons of nature are clearer than those of the authorities followed by Dr. Preller. That the kinds of rocks mentioned by them occur in certain districts is no doubt true, though their nomenclature is sometimes confused[2] and the suggested passages of one kind into another, where I have seen them, are due to the obliteration of their earlier history by intense crushing, or are consequences of thrust-faulting. For such a thing as the ascription of the calc-schists and crystalline limestones, with one group of the pietre verdi, to the Lias–Trias, and the mica-schists and minute gneisses, with another group of the same, to the Permo-Carboniferous (p. 307), no evidence is given; the matter at issue is quietly assumed. The general succession of the crystalline schists—micaceous, calcareous, and quartzose—and certain gneisses I do not dispute, for I sketched it out thirty years ago,[3] and have upheld it ever since, though, as I hope, I have obtained a clearer knowledge of the pietre verdi group and of certain of the porphyritic gneisses, which are pressure-modified intrusive granites, later in date on the whole than the aforesaid rocks, but do not, so far as I have seen in the Western and Central Alps, cut Palæozoic or later sedimentary rocks. The above-named schists are fairly abundant on both sides of the Pennines, especially the northern, as in the mountain region around Saas, Zermatt, Arolla, and Zinal, also in the Lepontine, Rhætian, and Central Tyrol Alps; in fact, I have examined them in many places from the Viso to the Gross Glockner—quartz-schists, calc-schists, and mica-schists. These rocks form long continuous zones, in which 'green schists' appear intermittently, and overlie a variety of coarser and stronger mica-schists and gneisses, below which are large masses of granitoid rocks, which, though apparently the older, are, in many cases at least, certainly the newer.[4] But there is nothing to prove that the schists are of Trias–Lias age, only that here and there little strips, sometimes only a few yards in length and feet in breadth, are wedged in among the gneisses or crystalline schists. No one accustomed to the last-named group of rocks would have dreamt for a moment that the friable unaltered rauchwacké could possibly form part of one and the same series with

[1] Geol. Mag., 1901, p. 161.

[2] For instance, the *schistes lustrées* have been for long a "waiting-room" where rocks in very different states of metamorphism are left till called for.

[3] Q.J.G.S., 1886, Proc., p. 79. A generally similar succession of crystalline schists (originally sediments) occurs in the Highland zone between Dunkeld and Braemar, and hornblende schists (grüner schiefer of the coarser type) in the North-West Highlands. Id., pp. 91, 92.

[4] Papers dealing with different points in the nature and succession of these rocks will be found in *Min. Mag.*, 1887, pp. 1, 191; Geol. Mag., 1887, p. 573; 1889, p. 483; 1890, p. 533; 1893, p. 204; 1894, p. 114; 1896, p. 400; 1897, p. 110; *Phil. Mag.*, 1892, p. 237; and Q.J.G.S., 1889, p. 67; 1890, p. 187; 1893, pp. 89, 94, 104; 1894, pp. 279, 285; 1897, p. 16; 1898, p. 357; 1903, p. 55; 1905, p. 690; 1908, p. 152.

them and have undergone a similar amount of heat and pressure, especially the former.

One word in conclusion. The reader of Dr. Preller's papers will soon discover that he quotes as if they were authorities of equal value geologists who often express contradictory views. If one man says a group of rocks is late Palæozoic or early Mesozoic, and another that it is Archæan, one of the two must be wrong, so hopelessly that it is no use quoting his opinion. Which of them seems to me to be right will be obvious from what I have written. This expresses opinions not lightly formed. More than thirty years ago I found the views (not of Italian geologists only) so widely discordant that I ceased to study their writings for any other purpose than finding out the position of sections supposed to be critical. From these I have been collecting evidence, by personal examination, visiting, on an average at least once in a year from 1881 to 1911, one or other important district, so as to test repeatedly the hypotheses both of myself and of others. The knowledge thus acquired emboldens me, audacious as it may seem, to express my complete dissent from those geologists who assert the existence of true schists and gneisses of Permian to Liassic age anywhere in the Alpine chain.

NOTICES OF MEMOIRS.

I.—Report of the Joint Discussion on Coal at the Newcastle Meeting of the British Association.

AMONG the more important items in the programme of Section C at Newcastle may be mentioned the discussion with the members of the Chemical Section on "The investigation of the chemical and geological characters of coal, with a view to its most effective utilization as fuel and to the extraction of by-products". The discussion formed a natural and appropriate corollary to the President's address. A desire to abolish the present haphazard methods of utilizing coal—the natural outcome of the backward state of our knowledge of the mineral and its many varieties—was the keynote of the debate; and the desire found immediate expression in the formation of a research committee of Section C to deal with the matter, as well as in the nomination of geological members to serve on the committee of Section B dealing with Fuel Economy.

The discussion was most appropriately opened by Professor G. A. Lebour, who said that the geologist regards coal as a *rock* disposed in layers or seams sandwiched between a roof and a floor of other rocks, and subject to changes in thickness and to interruptions of continuity of various kinds. There are also changes in physical properties and composition, to investigate which he needs the help of others. It is his business to find the coal either by mapping the outcrops or, where there are none, by weighing circumstantial stratigraphical evidence of all sorts. He thus points out the possible extension of known, or the existence of hidden, coalfields. As to the composition of the coal in the seam as a whole, or in the different parts of the seam, he turns to the chemist for information. There is

wanted an agreed classification of coals based on both physical and chemical characters. He asked help from the chemists in providing such a classification, with a clear definition of each variety. The value of the analyses provided by the chemists would be greatly enhanced, from the geological point of view, if they could be informed of the nature of roof and floor respectively, since both are factors which undoubtedly influence the composition and properties of the coal between them. It was also very desirable that the analyses should be presented somewhat more uniformly drawn up than is the case at present. For geological purposes an ultimate analysis is of little or no use alone, but should be given together with one of the ordinary commercial kind, in which the percentage of free carbon, volatile matter, and ash is shown. One seam in the Newcastle Coal-field yielded in the north the best household coal, in the centre of its area the best coking coal, and, further south, the best steam coal of the district. He concluded by saying that after fifty years of work at coal he knew less what it really was than he thought he knew at first.

Professor W. A. Bone said he found it difficult to make any very definite statement about the chemical nature of coal, of which we were still largely ignorant. The technical chemist was in the habit of making certain tests with a view to judging the suitability of a given coal for particular economic purposes, and the ultimate composition of the coal substance can be determined with considerable accuracy. But such data, however useful as a guide to the user of coal, gave little or no information as to the chemical structure of coal. Within recent years a good deal of work had been done upon the action of various organic solvents, notably pyridine, upon coal, upon the results of which certain tentative conclusions had been drawn as to two different types of constituents (sometimes termed the 'resinous' and 'cellulosic or humic' types respectively) which are supposed to make up the coal substance, and this seemed to be a promising line of attack upon the problem. But it was too soon yet to put forward anything more certain than a working hypothesis. During the past thirty years a number of eminent chemists had individually attacked the problem of the chemical structure of coal on different lines, but little or nothing had been done to co-ordinate these various researches or to review their results in any active manner. In his opinion no great progress was likely to be made except on the lines of some well-considered scheme of research in which the various workers would find their place and collaborate. The Fuel Economy Committee had the matter in hand, and if the geologists wished to be more largely represented their further valued assistance would be welcomed by the chemists.

Professor Kendall (Leeds University) addressed himself particularly to the question of the nature and origin of the ash in coal-seams, a subject of great economic and geological importance. He recognized three sources of the mineral substances found in coal-seams—first, the residue of the actual mineral constituents of the plants composing the coal; second, detrital mineral matter, generally fine dust or mud, that had been blown or washed into the area of coal-formation; and

third, the sparry substances, generally calcite or iron pyrites, segregated as veins in the seams. The ordinary method of making an analysis for commercial purposes would not, of course, discriminate between these. A certain weight of coal was taken as nearly as possible representative of the whole seam, and after being broken into small particles was sampled and the fraction analysed. This gave no details as to the location of the respective types of ash, observation upon the seam under ground, or of the coal as marketed, nor showed how the sparry material was disposed in the 'cleat' or system of joints traversing bituminous coal. The work done in Newcastle by Dr. Garrett and the late Mr. Burton, who obtained radiographs of slices of coal, promised results of great interest; other means were also available. It is well known that ordinary coal consists of alternating bright and dull layers, and the late Professor A. H. Green obtained separate analyses of these two types, showing that the bright layers yield a very low ash percentage, while the dull charcoal layers may contain a much higher proportion. This has been confirmed by general experience. Another method employed for the purpose of deciding whether a coal would be improved by washing was to crush it down to fine granules, $\frac{1}{16}$ in. in diameter, and separate by specific gravity into moieties respectively of 1·2–1·3 and 1·3–1·4. The former in cases cited proved to be bright and lustrous, and to have an ash content amounting to only one-fifth of that found in the heavier sample, which was of a dull aspect. The inference has been drawn from the very low ash content of anthracite that it was composed of a different assemblage of plants from those producing the more bituminous seams or parts of the same seam. The speaker demurred to this, and pointed out that low ash is not a universal characteristic of anthracites, but also that two features of anthracite seams combined to give a low ash, the dull layers are generally of very small dimensions, and anthracite, the world over, is destitute of 'cleat'. The contention that the sparry infilling of 'cleat' crevices in bituminous coal is derived from the coal, seems contradicted by its composition—the high percentage of calcium carbonate and of iron and low potash in the ash taken as a whole is the reverse of what would be found in any average assemblage of plants, and the speaker would regard the lime and the iron as introduced bp percolation from the measures. It is much to be desired that geologists, chemists, and palæobotanists should combine to make exhaustive studies of a seam from floor to roof, and also to extend their scrutiny to the variations of a given seam from place to place, so that such anomalies could be explained as that of a well-known seam in Yorkshire that in two adjacent pits passes from a 'coking' to a 'non-coking' condition.

Dr. Dunn thought the discussion showed the need of co-operation and collaboration, not only of the chemical workers, as suggested by Dr. Bone, but of geologists and botanists with the chemists. Professor Lebour had blamed the chemists for not furnishing a philosophical classification of coals; but classification depended partly on the purpose to be served by it, and partly on the extent of our knowledge of the things to be classified. Such classifications as had been

attempted had had in view chiefly the various uses of coal, and had no pretensions to being scientific or philosophical, or indicative of the real nature of various coals; and our knowledge of that nature was so rudimentary and incomplete that no true classification was possible. Analyses of coal, too, had chiefly been made for users of coal, and the form which gave the information needed by one class of user might not be suitable for another; the geologists had hitherto for the most part been able to make use only of such analyses, and hence arose the lack of uniformity spoken of by Professor Lebour. All these analyses dealt with the products of the destruction of coal, not with the substances actually contained in it; though much work had been done in the endeavour to understand the nature of coal, very little progress had been made, and we knew little more than that coal contained two or three substances separable by different solvents, one of which seemed to be intimately connected with the coking properties of coal. The question of the ash of coal, raised by Professor Kendall, was a very important one, especially the separation of the inherent ash, or mineral matter originally contained in the plants from which the coal was derived, from the extraneous mineral matter, and also the distinction between ash irregularly distributed as 'dirt', 'stone', or 'shale' among the coal, and that found minutely subdivided throughout it. Great variations occurred in the composition of the ash; it was usually a complex mixture of silicates, but he had had one sample which was practically a pure china clay, and another which contained over 80 per cent of ferric oxide. Analyses of ash, like those of coal, were usually made by chemists who were unacquainted with the geological features of the occurrence of the coals concerned; and the problems raised by the geologist could never be enlightened by the chemist unless the whole of the circumstances were put before him, and analyses made on the geologist's own samples and for his own purposes. To do this completely, for a survey of all the coal-seams of the kingdom, will involve an enormous amount of labour, and will need not only hearty co-operation between chemists and geologists, but financial assistance on a scale that can hardly be furnished by any other body than the nation.

Professor Bedson dealt briefly with the investigations which had been made into the nature of the organic proximate constituents of coal. He drew attention to the reports of a committee of Section B published in the Transactions of the Association in 1894 and in 1896, and spoke of some of the more recent attempts to isolate the constituents of coal substances by the aid of solvents, amongst which pyridine and quinoline appear to be the most efficient. Although a considerable amount of work has been done, still we are lacking exact information as to the chemical nature of the substances dissolved and the undissolved portions.

Mr. D. Trevor Jones, speaking on behalf of Dr. R. V. Wheeler and himself, and dealing with the question of the constitution of coal from the chemical aspect, remarked that coal is considered to have been formed from decayed vegetable matter by the action of pressure and temperature. The temperature must have fallen short of 300° C. The coal conglomerate can be resolved by means of solvents into

cellulosic and resinic portions. The cellulosic derivatives contain compounds the molecules of which possess the furan structure and yield phenols when destructively distilled. There are also compounds present the molecules of which have structures resembling that of the carbon molecule, but it is unlikely that 'free' carbon is present in coal. The cellulosic derivatives are probably few in type. The resinic derivatives contain compounds in which alkyl, naphthene, and unsaturated hydroaromatic radicles are attached to larger and more complex groupings. It is doubtful whether aromatic groupings are present. Under the influence of pressure the bulk of the resinic derivatives have become highly polymerized. The oxygenated resinic derivatives are chiefly oxides, probably cyclic oxides; esters, lactones, anhydrides, acids, and ketones are absent or present only in small quantity. Hydrocarbons exist in the resinic portion of coal; saturated hydrocarbons (paraffins) are, however, present in small quantities only.

Dr. Marie C. Stopes, who had also been working in conjunction with Dr. Wheeler, said that in dealing with the composition of coal the chemist is faced with the difficulty that there are contained in it a number of different compounds which must be separated from one another before their characters can be determined. The only clue to their composition is the fact (no longer seriously disputable) that they are of vegetable origin. In estimating the nature of coal unaltered by heat or chemical action, up to date the chemist has done no more than, by means of solvents, roughly to separate coal into two main classes of constituents which have been termed 'cellulosic' and 'resinic'. Of these the 'cellulosic' constituents are separable into two groups. Palæobotany has established the fact that some, if not all, ordinary bituminous coals are formed from a mixture of various parts of land-plants.[1] No living plant is so simply divisible into two constituents as is coal into 'cellulosic' and 'resinic'; cellulose forms the major part of the cell-walls of the soft tissues, resin may be present in special cells or glands, and may possibly be modified from various cell contents, but the different portions of even the simplest land-plant are composed of a great variety of distinct chemical compounds, many of which have been named and classified by plant-physiologists. Though a number of these substances may be but slight variations of the 'cellulose' complex molecule, yet in the living plant they have distinctive work to do and have recognizably various morphological and physical properties. It is not unnatural to assume, therefore, that these various substances may be the sources of different chemical compounds now in coal. It will be readily understood that were different by-products from coal traceable to specific parts of plants, and these plant-remains were visually recognizable in the coal itself, a considerable step might be made in our knowledge of coals and their potentialities. For the individual plant portions might be isolated by suitable methods, and the substances for which they were responsible when coal is heated determined. (This is not invalidated by the fact that these portions may or may not differ in composition from the corresponding parts of living plants.) It is on such work that we are at present engaged,

[1] Though this is widely accepted it has been *proved* in very few cases.

using as the starting-point the instance that the phenols obtained when coal is destructively distilled are derived from that particular class of compounds grouped as 'cellulosic'. As plant mechanisms had evolved many distinctive forms of cellulose compounds even by the time of the Carboniferous epoch, we think it is necessary to ascertain whether the various modifications of cellulose differ materially in the compounds they yield, and if so which part of the plant substance corresponds to any particular coal-derivative. An illustration may be useful here: Conspicuous in the construction of many coals are the small yellow bodies known to everyone as spores. Their walls are formed of a derivative of cellulose. Are they, or are they not, still in a condition to react distinctively to treatment by pyridine? Those who have experience in the examination of coals will recognize the practical difficulties in the way of answering so apparently simple a question, for hitherto spores have not been recognizable in lump coal but in thin sections, while, on the other hand, thin sections are not suitable for extraction by pyridine. Nevertheless the difficulties have been overcome, and in the insoluble residue of coal extracted by pyridine we have observed unaltered spores in large numbers. This proves that the particular modification of cellulose forming their walls is one of the 'cellulosic' derivatives insoluble in pyridine. Since some coals are largely composed of spores this fact is of some value, more particularly as spores have a most distinctive appearance and are generally recognizable in thin sections. The next stage in the work is the isolation from coal of a sufficient number of spores to make possible a chemical examination to ascertain what particular type of chemical compounds they yield on destructive distillation. Spores, though the most conspicuous, are by no means the principal constituents of most coals; wood, soft parenchyma, cork, chlorophyll-containing or green tissues of leaves, must all have been universally present in proportions varying from inch to inch in the mass of débris from which any humic coal was formed. Cuticles, morphologically very distinctive portions of plants, and at the same time largely formed of a specific chemical compound to which the name cutin has been given, are conspicuous in the coal substance. We have now isolated sufficient pure cuticles from coal to distil them separately. It will be our business to track down the substances in coal one by one and to isolate them in such a form as will render their chemical examination possible. To hunt this extremely elusive game the microscope is necessary, and the chemist alone is unable to interpret what is to be seen on its field; the palæobotanist alone cannot probe into the chemical composition of even the plant-structures he best recognizes. This is obviously a case for co-operation. The practical aim of such work should be to devise methods whereby satisfactory evidence can be obtained as to the most economic use to which a given seam can be put, coal being regarded not only as a fuel but as the source of innumerable, and some perhaps unsuspected, materials of increasing importance in modern life. The ultimate aim of the research is a complete scientific knowledge of the chemical composition and mode of formation of coal.

Dr. Hickling desired to support all that had been said by the

preceding speaker regarding the supreme importance of the closest co-operation between chemical and microscopical investigators of coal-substance, and of both with the work of the field-geologist, if we are to ensure the most intelligent and profitable use of our coal resources. The great importance of the problems involved no one would question, and the experience he had had in their investigation had convinced him that only a considerable body of workers dealing in close co-operation with all branches of the subject could hope to attain in reasonable time to the ends desired. He strongly hoped that this discussion might have such an issue. In one particular he desired to differ slightly from Dr. Stopes; while all agreed that every true coal was a mass of more or less decomposed vegetable material, he was inclined to suspect that, in general, it was the amount and character of the decomposition which determined the quality of the coal, rather than the nature of the original plants. Certainly it would be unwise to assume that any very intimate relationship must exist between the original composition of a given plant-structure, and the composition of the coal-substance into which that structure is now converted. Palæobotanists would remember that the most beautifully preserved plant-tissues consisted almost wholly of calcium carbonate or silica, and similarly in coal itself the original constituents of the cell-walls, etc., may be very extensively replaced by other materials, though the materials in this case are the decomposition products of the plants themselves. He regarded the co-operation of various classes of workers as especially necessary in discriminating the highly complex association of varied materials which entered into the composition of every coal-seam. The field-geologist readily recognized the sharply defined and distinguished 'bright' and 'dull' bands or lenticles of the seam, while the microscopist was able to confirm the important differences between them. But the microscope enabled us to go much further, and to recognize that two samples of 'bright' coal, indistinguishable in the hand-specimen, are nevertheless widely different in minute constitution. The chemist, on the other hand, so far as any attempt at all had been made in the rational selection of material for analysis, had been in the habit of preparing a carefully mixed sample of all parts of the seam to be investigated. The analysis of such a sample, while possessing a certain commercial value, was clearly of the smallest possible value as a clue to the real constitution of any of the varied substances which are grouped together as coal. He was convinced that a scientific understanding of coals, the obvious pre-requisite of their best utilization, could only be attained by the investigation separately of the many distinct elements of seams which the eye and the microscope revealed.

Professor Fearnsides expressed the hope that out of the present discussion would come a recognition by chemists that ultimate analyses of coals are required for purposes other than the mere determination of the equitable selling price of the coal by the truck. He dealt with the subject of coal as a rock genus, within which quite a number of essentially different species have already been distinguished by geologists and others, and asked that chemists should undertake to express these known differences in terms of the chemical constitution

of the coals. He thought that all geologists would recognize the importance of the results which have been already obtained by the study of the behaviour of coals when extracted with various solvents. He had himself come up against some of the technical difficulties mentioned in the paper by Drs. Wheeler & Stopes, which invalidate the results which might be expected from the direct extraction of transparent micro-preparations of coal with pyridine or chloroform, but from his own experiments he was led to expect that the methods of the metallographer, applied to cleat surfaces or polished specimens of coal etched with these solvents, may provide the information which is immediately required. He wished to support Dr. Hickling's contention that whenever a chemical analysis of a sound block of coal is undertaken, opportunity should be given for the palæobotanists to ascertain the microscopic structure of a corresponding portion of that same piece of coal. He expressed the opinion that great mutual advantage would accrue if the chemists would co-operate with field-geologists and mine workers in the choosing of the samples of coal which are worthy of analysis. He suggested in particular that one of the directions in which this co-operation between chemists and geologists was most to be desired was to secure a real knowledge of the lateral variations of composition within the individual lenticles of coal, which in sum constitute the wide-spreading beds of rock which are known as coal-seams.

Professor Boyd Dawkins emphasized the point raised by Dr. Hickling that the apparent identity in structure of certain parts of the coal with the cell-structure of the living plant does not necessarily prove that the original tissues of the plants have been preserved. It is a matter of common geological knowledge that very generally in the process of fossilization the original tissues, both of plants and animals, have been replaced atom by atom by carbonate of lime or silica, or even iron pyrites, without the details of structure having been destroyed. Sometimes, as in the case of the deposit of calcite in wooden troughs in coal-pits, the structure of the wood, including the growth-lines and medullary rays, is faithfully reproduced. In specimens in the Manchester Museum the calcite cast of the interior of sea-urchins, from the Coral Rag, has carried the pattern of the test into the very centre, as the mineral slowly filtered through the wall. This point must be considered by the palæobotanists, who are doing their share of work in dealing with the history of coal. In his opinion the greater part, if not the whole, of the organic element in the coal had been subjected to mineral change.

Professor W. S. Boulton (who presided) expressed his gratification at the opportunity for an interchange of ideas among chemists and geologists upon a subject of vital importance to the nation. Already, much valuable research upon the nature and composition of coal had been done, both on the analytical and on the microscopical and palæobotanical side. He felt sure that when the printed records of the discussion were published, they would serve to stimulate to fresh and more vigorous research, and more especially to co-ordinate and mutually assist the work of the chemist and geologist, and so enormously increase the value of our greatest industrial asset.

II.—The Ealing Scientific and Microscopical Society.

The 39th Annual Report, issued October, 1916 (8vo, pp. xiv + 14), contains, in addition to the affairs of the Society, etc., abstracts of lectures given in the past year, viz.: (1) "Coloration in Mollusca," by B. B. Woodward, F.L.S., F.G.S., F.R.M.S.; (2) "Meteorites and Shooting Stars," by Spencer L. Fletcher, F.R.A.S. (see below); (3) "Colour Photography," by Cyril M. Neaves; (4) High Explosives," by George Senter, D.Sc., Ph.D., F.I.C.; (5) "Are the Planets Inhabited?" by E. Walter Maunder, F.R.A.S.

Meteorites and Shooting Stars. By Spencer L. Fletcher, F.R.A.S.

THE ancients have left reports of stones falling from heaven which were treated as being of supernatural origin, until scientific investigation of phenomena began. Until 150 years ago the scientist either doubted the actuality of such falls of stones, or explained them as caused by stones projected by terrestrial forces (such as whirlwinds or volcanic eruptions) or manufactured in the clouds from particles of dust. If a stone was found heated or partly melted the theory was that it had been struck by lightning. Such ideas were negatived by well-attested falls of meteorites, from that at Dijon in 1761, which could not be reconciled with such origins.

Mr. Fletcher showed a number of views of meteorites, photographed from actual meteorites in the Natural History Museum. He explained that they are divided into aerolites, which are of stone; siderolites, which are partly stone and partly metal; and siderites, which are wholly metal (usually iron mixed with nickel). In many cases their fall is accompanied by a flash of light and loud explosions. A single stone may be found or there may be a shower of stones (from bursting), as at Poltusk in 1868. A notable case was the great meteorite which in 1719 was visible from Aberdeen to Paris, and, passing over the length of England, appears to have fallen into the sea. In that instance, besides the bright light and explosions, the tremor of the air was noted by Halley. Another great siderolite fell at Estherville, Iowa, in 1879, from a clear sky (showing that it had no connexion with clouds), and, bursting, scattered fragments over two miles, one weighing 431 pounds. The conclusion is that these lumps of stone and metal travel in outer space with great velocity, and burn away, wholly or partially, by friction, after entering our atmosphere.

They do not become visible until they reach our atmosphere, and have been observed at heights of 70 miles or less. It has been assumed that, at an earlier period of the earth's history, it possessed much larger volcanoes than any now existing, which threw up stones with such force as to conquer gravitation, so that the stones, instead of falling back to the earth, remained travelling in orbits around the sun, re-crossing our own orbit at every revolution. To conquer the earth's gravitation it would be necessary for the fragments to be projected with a velocity of at least seven miles per second. No volcano of the present day possesses sufficient power to do this, and there is no trace of the greater volcanoes which the theory supposes. This does not of itself, however, disprove the theory, as, since the earth's primeval crust was produced, sedimentary strata amounting to many miles in thickness have been formed, and no

trace of the original crust remains. If the theory is applied to the moon, where there is less gravitation, and there undoubtedly were once immense active volcanoes, it accounts well for some of the slower moving meteorites, which may have been travelling round the sun in orbits which intersected our own, since the time when the moon's volcanoes were active.

Their most probable origin is to be found in the primeval nebula, of which the comets are fragments. Comets travel in orbits round the sun, which are longer and narrower than the orbits of the planets. Passing too near a planet, a comet may become captured by its attraction, and have to revolve in a new orbit, which carries it around the sun, and then back to the place where the planet captured it. It thus becomes a short period comet.

When comets first become visible to us they are tailless, but as they approach the sun the tail appears and grows, and is usually repelled by the sun. The heat of the sun drives vapours out of the head of the comet (which consists of a cluster of meteors); the electrons thrown out by the sun condense these vapours into particles so small that they can be repelled by the sun's light against gravitation, thus forming the tail. The tenuous character of the tail is clear from the fact that it does not obscure the stars from our vision.

To sum up the history of these bodies, Mr. Fletcher went back to the nebula, from which all stars are formed. It condenses into a system like our Solar System, but some fragments or wisps are left out, which form the heads of comets and travel round the central sun in long orbits. They are caught by planets and reduced to smaller orbits. The emission of the tail gradually wears them out till they become tailless, and are reduced to streams of meteors. These get in time strewn round their orbits. Then the question arises, are meteorites and shooting stars the same? In general it would seem so, but in that case the meteorites which reach the earth in tangible form must be the very largest shooting stars, as the usual shower of them only produces the finest dust.

III.—Historical Manuscripts Commission: The Early Water Supply of Exeter.

IN the *Report on the Records of the City of Exeter*, just issued by the Historical Manuscripts Commission (characterized by the halfpenny Press as "waste of paper"), will be found the following interesting documents relating to the water supply of Exeter City.

"1260. The Prior and Convent of St. Nicholas grant leave to Martin Durling and his heirs to draw water 'ab aqueducto que est in cemeterio nostro ce Occidentali parte ecclesia nostre per gardinum nostrum quod est in occidentali parte que ducit a magno vico usque ad Fratres Minores'."

"1299. Agreement on the part of the Mayor and Commonalty of Exeter by consent of Edmund, Earl of Cornwall, with Henry de Bolleg', Archdeacon of Totnes, concerning the building of a tower next the said Archdeacon's house—'per quam communis aqua civitatis ingreditur.'"

"1346. Settlement of a dispute between the Prior of St. Nicholas on the one side and the Dean and Chapter of the Cathedral and the Mayor, etc., on the other, in regard to the making and repairing of the common water 'conduit', the water of which rises without the East Gate in St. Sidwell's parish."

"1347. King Edward III grants to the Warden and Convent of the Grey Friars of Exeter 'quod ipsi duos modicos [*sic*] atque ortus se jungentes in profunditate fossati civitatis Exon inter orientalem et australem portas ejusdem civitatis profundius fodere et muro lapideo basso includere et aquam de ortibus illis sive fonte inde facto exinde per fistulam subterraneam in fossato predicto et ultra stratam regiam usque ad domum sive habitacionem fratrum predictorum, qua in loco sicco situatur et ad quam aque cursus non habitur, ponendam ducere ac caput fontis predicti dictamque fistulam quotiens reparacione et emandacione indigent reparare et emendare ac de novo construere et facere prout magis expedire viderint', etc."

"1444. The chamber obtain licence to dig for water in St. Sidwell's Fee and to carry away the water in leaden pipes to the new conduit."

"1534. 'Mdm. that John Newtun and John Geboons beganne to make the grete condet of Exsetur the viij day of Novembre, and here folowyth the costes and charges.' 'Thys ys the hole boke, the sum thereof trewly caste as y can do—xxviij*li.* x*s.* viij*d.*'"

"1600 and 1649. Contracts made to lay new leaden pipes to the conduits and cisterns of the city."

"1694. Contract concerning the waterworks and the supplying of the city with water. And in 1695 the Mayor, etc., make a grant of the waterworks of the city and several parcels of land for a term of 200 years."

The last document brings the matter almost to our own days.

REVIEWS.

I.—Geology and the Panama Canal.

THE United States Department of the Interior (Bureau of Mines) has issued a Bulletin (No. 86) by Donald F. Macdonald on "Some Engineering Problems of the Panama Canal in their relation to Geology and Topography". This extremely interesting publication (price 45 cents) deals with topographic types, climate, streams, valleys, coastal conditions, and their several relations to the works. It discusses the general geology and its connexion with the engineering problems as found in the sedimentary and the igneous masses cut through. Then with the structural geology, folding, faulting, shearing, fissuring, jointing, and intrusions; values of the various rock material for constructive work; stability of foundation rocks and conditions affecting the same; slides, their causes and remedies, with full details of the canal slides and illustrative slides from other areas and their cure; local heating of rock masses by chemical decomposition on weathering, by drilling or blasting; danger from earthquakes or earth-movement, etc. All which matter can be applied to any constructive works according to varying local conditions, and therefore of considerable value in handy octavo form. The pamphlet closes with a tabulation showing the cost per cubic yard of dry excavation, crushed stone, coarse rock, sand, masonry, etc., and provides bibliographies of 'slides' and methods of mining.—C. D. S.

II.—Thicknesses of Strata of the Counties of England and Wales. Memoirs of the Geological Survey. pp. vi + 172. 1916.

UNDER this title the Geological Survey have issued a summary of the chief facts regarding the thicknesses of the newer strata of England and Wales. The authors wisely limit themselves to

strata newer than the Carboniferous; since, as is set forth in the preface, measured thicknesses of rocks older than this period are of little or no value; while as for the Carboniferous system itself, records are so numerous that there is little need to repeat them. The country is divided into counties, which are described either singly, or two or three together, where geographical or geological conditions make this necessary. Each area by itself forms the subject of a chapter, beginning with a map showing, as far as possible, all the places mentioned in the text. A general description of the rocks follows, beginning with the newest and going down to the oldest, in which the most important variations in thickness of each formation are discussed. Finally, a tabulated list of the records of the principal deep borings is added at the end of the chapter. The book affords an admirable and simple method of obtaining much information which could only be obtained hitherto by prolonged search through libraries.—W. H. W.

III.—Geitsi Gubib: an Old Volcano. By A. W. Rogers. Transactions of the Royal Society of South Africa, vol. v, pt. iii, December, 1915.

GEITSI Gubib is a ring-shaped mountain, rising 5,200 feet above sea-level, and 1,800 feet above the plateau north of Keetmanshoop in South-West Africa. The ring is from one mile to a mile and a quarter in diameter, and has a depression in the centre 1,500 feet below the highest point of the ring, which is drained by a stream flowing through a gap in its south-east side. The mountain itself is composed of fine-grained clastic rocks dipping steeply inwards. The junction with the Fish River Sandstones is vertical, and can be seen in the valley of the stream; in the same place it can be seen that the sandstones also dip inwards at the junction. The rocks themselves consist of breccias and tuffs; the breccias are formed of fine-grained sedimentary rocks, with some fragments related to the quartz gabbros, in a cement of quartz and dusty material. Fragments of orthoclase, plagioclase, and augite are found in them. The most notable features are the entire absence of true volcanic rocks and of large blocks, there being none above one inch in diameter. The silica cement seems to be harder and better developed round the outside of the mountain, and it is to this fact that it owes its ring-shape. This disposition of the cement is almost certainly due to the rising of waters charged with silica round the margin of the vent. No trace of the fragmental material which was thrown out on to the surrounding country now remains, and it is obvious that the original cone and surface have been worn away, leaving the hardened plug standing above the present plateau. The depression in the centre is therefore not a crater, though it occupies the same relative position. Dr. Rogers suggests two possible origins for the mountain; these are, first, that it was an ordinary explosive crater, and second, that the clastic rocks have been let down by a circular fault. Of these the first is more probable, as there is little brecciation along the line of junction; and it is also borne out by the existence of sattelite pipes with igneous

material in the neighbourhood. The age of the mountain is quite uncertain; it may be post-Karroo, as a fragment of rock, probably of Karroo age, was found in the vent, but this is by no means proved.—W. H. W.

IV.—Zircon, Monazite, and other Minerals used in the Production of Chemical Compounds employed in the Manufacture of Lighting Apparatus. Bull. No. 25, North Carolina Geological Survey. 1916.

THIS publication with a clumsy title contains a very interesting account of the occurrence and exploitation of the large number of rare-earth minerals that are now used in the manufacture of incandescent gas-mantles and filaments for electric lamps. The minerals now used on a large scale for these purposes are monazite, zircon, gadolinite, columbite, tantalite, and wolframite. Other minerals capable of being used for the same purposes if found in sufficient quantity are also dealt with. As is well known, many of them are found in considerable quantity in North Carolina, especially monazite and zircon. The processes employed in mining and manufacture are also described in an attractive manner.—R. H. R.

V.—Geology of the Cranbrook Map-area, British Columbia. By S. J. Schofield. Canada, Dept. of Mines, Geological Survey Mem. 76. pp. 245. Ottawa, 1915.

THE area described in this memoir consists mainly of the central portion of the Purcell Range, an area that once formed the western flank of the ancient Rocky Mountain geosyncline. A detailed account of the Purcell Series (of Beltian age) and of the well-known Purcell and Moyie sills is given. On the east the Purcell sediments continue underneath an unconformable blanket of Palæozoic formations, while to the west there still remain patches of pre-Beltian schists that seem to be relics of the parent land from which the Purcell Series was derived. The Purcell sills consist of hornblende gabbro accompanied by irregular masses of hornblende granite, and with the latter copper deposits of some importance are associated. However, the area owes its economic prosperity more particularly to the presence of valuable silver-lead deposits associated genetically with small stocks of granite that for the present are thought to be of Jurassic age. The memoir is copiously illustrated with thirty-three plates and is accompanied by a coloured geological map.—A. H.

VI.—The Geology of Parahyba and Rio Grande do Norte, Brazil. By R. H. Soper. Proc. Am. Phil. Soc., vol. li, pp. 1–20, 1916.

WITH the exception of a narrow belt along the coast and a few isolated patches of the interior, the whole of the two states is made up of the crystalline rocks known broadly as the Brazilian complex. This consists of gneisses and schists thickly threaded with quartz veins and pegmatites, and intruded upon by numerous bosses of granite which form the axes of the principal serras. Along the

coastal belt the rocks are sedimentary and range in age from Cretaceous to Recent. The author divides them into three groups: (1) sandstones with fossils; (2) limestones belonging to the late Cretaceous and early Tertiary; and (3) sands and clays (probably of late Tertiary age) surmounted in places by recent sand dunes and other deposits. The topography of the country seems to approximate to the 'inselberg' type of landscape, for Mr. Soper describes it as "characterized by great undulating plains, abrupt mountains, rocky, steep-sided hills, and peaked serrotes".—A. H.

VII.—Nepheline Syenites of Haliburton County, Ontario. By W. G. Foye. Am. Journ. Sci., vol. xl, pp. 413–36, October, 1915.

THE author describes two differentiated laccoliths of nepheline syenite that lie in a syncline of limestone between large areas of Laurentian gneiss. He then discusses the origin of the alkaline intrusions, and states his agreement with Professor Smyth's opinion that nepheline and sodalite rocks are results of the pneumatolytic phase of igneous activity in certain circumstances. In this instance Mr. Foye suggests that the controlling circumstances consisted in the desilication of granite magma during its *lit-par-lit* injection into the Grenville limestones. "Soda solutions were given off by the granite magma because lime was capable of replacing soda at high temperatures" (p. 434). From granite and limestone as the parent materials, amphibolite and nepheline syenite were, it is believed, thus derived, and the close field associations of these four types of rock provides the theory with an assemblage of facts that ought on further elucidation to lead to its complete demonstration.—A. H.

REPORTS AND PROCEEDINGS.

Geological Society of Glasgow.

At a meeting of the Society on October 12, Mr. G. W. Tyrrell exhibited, on behalf of Mr. B. K. N. Wyllie, a number of Stone Age artifacts from Northern Ashanti. These are of three types: (1) rough chips and flakes of quartz; (2) chisel- or celt-shaped polished stones; (3) artifacts with a herring-bone or cross pattern. The first two types are common throughout the Gold Coast Colony, but the third is rare, the specimens exhibited being found at Temma, 100 miles north of Coomassie, in a remarkable natural stronghold. The latter consisted of a rectangular block of current-bedded sandstone, 200 to 300 yards long by 100 yards broad, and nearly 200 feet high, standing with sheer walls on the low slope at the side of a wide valley. The patterned objects and the celts were found on the floor of a small cirque inside this, which may have been adopted as a fortress or a fetish monastery by an earlier race of inhabitants; the local Ashantis display utter ignorance of the originators of these things, and their fetish methods are totally different. A piece of iron slag was also found inside the cirque.

Dr. C. H. Desch read a paper, illustrated by lantern slides and specimens, on "The Origin of Agates". The most puzzling question in regard to agates was the parallel banding of the chalcedony of which they were chiefly composed. This had usually been regarded as representing successive flows of liquid containing gelatinous silica, which was deposited in thin layers on the walls of the cavity in which the agate was formed. Certain features common in agates were regarded as "tubes of entry" or "tubes of escape". In 1867 Ruskin had brought forward evidence to show that the banding was due rather to segregation in the solid state, but no theory as to the mechanism of the process could then be given. The work of Liesegang on rhythmical precipitation in gelatinous masses had led to the production of objects in which all the characteristic features of agates, including the "tubes of escape", were exactly imitated by processes of simple diffusion. It was not even necessary to assume precipitation. Slides were shown to prove that rhythmical crystallization, giving rise to a banded structure, could be observed even in pure substances. It was sufficient to assume a process of rhythmical crystallization in a mass of gelatinous silica to account for the banding and other characteristic features of agates.

OBITUARY.

C. T. CLOUGH,

M.A., LL.D., F.G.S., F.R.S.E., of Geological Survey of Great Britain.

BORN DECEMBER 23, 1852. DIED AUGUST 27, 1916.

AN accident on the railway near Bo'ness has cut short the life of one of the most widely known and deeply respected of British geologists. Dr. Clough in the course of field-work in that district had occasion to cross the railway. Some mineral wagons were being shunted at the time and he tried to pass in front of them, but was run over. Immediate attention was given to him, first by the railway staff, and thereafter by the surgeons of Edinburgh Infirmary, to which he was sent by special train, but his injuries were very serious, involving double amputation, and after lingering for three days he died on Sunday, August 27, 1916. He was buried in Lasswade Churchyard on Wednesday, August 30.

Dr. Clough was 63 years of age. He joined the Geological Survey in March, 1875, at the age of 22, and after forty-one years was on the eve of retiring, but consented to remain on the staff to assist in meeting the pressure of work entailed by the absence on active service of most of the junior members of the Survey.

He was educated at Rugby, and at St. John's College, Cambridge, which he entered in October, 1871. He was awarded an exhibition in Natural Science from 1872 to 1874. In 1873 he obtained a first class in the May examination. In 1874 he received a first class in the Natural Science Tripos, being bracketed second with Herbert Carpenter, J. N. Langley, R. D. Roberts, and C. E. Shelly. He was elected a scholar in 1874–5, and took his B.A. in 1875 and his M.A. in 1878.

His first work on the Survey was done under the late H. H. Howell in the North of England. Teesdale, a district for which he preserved a lifelong affection, was the scene of his earliest field-work; and his first paper, printed in the Quarterly Journal of the Geological Society in 1876 (vol. xxxii), was on "The Section at the High Force, Teesdale". He continued in Northumberland and Durham for eight years, and the results of his work appeared in several Survey memoirs, including *Otterburn and Elsdon* (Sheet 108 S.E.) and *The English Side of the Cheviot Hills* (Sheet 108 N.E.).

In 1884 the one-inch map of England and Wales was completed, and Clough, along with Gunn, Barrow, and Hugh Miller, was transferred to Scotland. The survey of the North-West Highlands was then beginning, and Clough took part in it, but in the autumn and spring seasons he was engaged in surveying the Cowal district of Argyllshire. In Sutherlandshire he mapped a large district north of Loch Glencoul to Loch Inchard, and subsequently he executed the survey of an extensive area around Loch Maree. His description of that ground is contained in the Survey memoir on the North-West Highlands. When this was completed he worked in Glenelg, the north-east part of Skye, and Soay. About 1900 he was transferred to Strathcarron, Eastern Ross-shire. In 1902, on the death of W. Gunn, Clough became a District Geologist. He continued for a time in Ross-shire, and subsequently took charge of the work in northern Argyllshire and in Mull. In the spring and autumn seasons he was also employed on the revision of the coal-fields which was started in 1900. His first work of this description was in Haddingtonshire and the Lothians coal-field, and when that was completed he was transferred to Bo'ness. Subsequently he had charge of the revision of the Lanarkshire coal-field in the district south-east of Glasgow (Holytown, Motherwell, Airdrie), and finally he superintended the work in the North Ayrshire coal-field.

As time went on he exhibited a certain reluctance to publishing geological papers in the transactions of societies and in journals, and most of the results of his field-work appeared in Survey memoirs and maps. Of these perhaps the best known are the *Geology of Cowal* (1897), *Geology of the Neighbourhood of Edinburgh* (1910), *Geology of the Glasgow District* (1911), *Geology of Ben Wyvis* (1912), and the *Geology of Glenelg* (1910). At the time of his death he had two important memoirs on hand, viz. *The Economic Geology of the Central Coal-field of Scotland* and the *Geology of Mull*. Dr. Clough had contributed to thirteen Scottish and five English memoirs of the Geological Survey.

In field-work and the preparation of maps Dr. Clough found his principal interest. Office work and the writing of memoirs and scientific papers were more or less irksome to him. He combined to an extraordinary degree powers of minute observation, great diligence, and enthusiasm. His working day was always a very long one, and no difficulties arising from the complexity of the structural features of the ground assigned to him ever depressed him. In fact, he revelled in the mapping of intricate geology. Some of his field maps of the North-West Highlands, of Mull, and of Central Ayrshire may be

cited as examples of detailed mapping on the six-inch scale which, for thoroughness, have never been surpassed. He was a very judicious and impartial observer, and extremely cautious in drawing inferences. These qualities were especially valuable in mapping the Scottish coal-fields, where faulting and igneous intrusions play an important part. Mining engineers freely recognized Dr. Clough's pre-eminence in this class of work and placed great reliance on his opinion. The excellent training which he received from H. H. Howell no doubt laid the foundation of his eminence in field geology.

In the much debated questions of Highland geology and metamorphism Dr. Clough was intensely interested, and keenly alive to the importance of new discoveries. Yet he avoided speculation and declined to formulate general hypotheses till he felt sure the evidence was sufficient. Once convinced, however, he took up a well-defined position and was able to maintain it against all critics. His contributions to the memoir on Ben Wyvis shows a broad grasp of the problems involved. In later years he was a strong supporter of the interpretation of the structure of the Fort William country which was advanced by Bailey and Maufe. The important paper on the Cauldron Subsidence of Glencoe, which he wrote along with the two above-named geologists, had wide bearings on the tectonics of the Highlands. The still more difficult problems of the Tertiary Volcanic Rocks of Mull during the last years of his life deeply absorbed his attention.

He had a strong personality, which has left its stamp both on his work and on the men whom he trained in field geology, many of whom have attained distinction in scientific work. His watchwords were thoroughness and veracity, even in the minutest, apparently insignificant details. His habits were of extreme simplicity, and he was perfectly content with the rough food and simple life of a Highland shepherd's cottage. One of the most unassuming of men, he was never known to utter a harsh criticism, and he treated the opinions of even the youngest geologist with sincere respect. His gentleness, kindness of heart, and helpfulness earned him the affection of all with whom he came in contact. Questions of social reform attracted him strongly, though he paid little attention to politics as a whole.

Dr. Clough was a Fellow of the Royal Society of Edinburgh, and of the Geological Society of London, which, in 1906, awarded him the Murchison Medal. In July of the present year the University of St. Andrews conferred on him the honorary degree of LL.D. He was President of the Geological Society of Edinburgh from 1908 to 1910. He leaves a widow, two daughters, and a son, who is now in Canada and is serving with the R.A.M.C.

MISCELLANEOUS.

Human Skeleton in *Glacial* Deposits, Ipswich.[1]

We have received the following letter published in the *Evening Star* and *East Anglian Daily Times* (dated October 14, 1916):—

[1] See Geol. Mag., 1912, pp. 165, 187, 239, 287.

"Mr. J. Reid Moir writes:—It will no doubt be remembered that at the time of the discovery in 1911 of a human skeleton in a sand pit in the occupation of Messrs. A. Bolton and Co., Ltd. (late Bolton and Laughlin) of Henley Road, Ipswich, it was held by some geologists and by myself that the remains occurred beneath an undisturbed stratum of weathered chalky boulder clay. Since this discovery I have been enabled to investigate extensively the small valley adjoining the sand pit in which the human skeleton was found, and to conduct excavations in the immediate vicinity of the spot where the bones occurred.

"These investigations have shown that at about the level at which the skeleton rested the scanty remains of a 'floor' are present, and that the few associated flint implements appear to be the same as others found on an old occupation-level in the adjacent valley. This occupation-level is in all probability referable to the early Aurignac period, and it appears that the person whose remains were discovered was buried in this old land surface. The material which has since covered the ancient 'floor' may be regarded as a sludge, formed largely of re-made boulder clay, and that its deposition was probably associated with a period of low temperature occurring in post-chalky boulder clay times.

"It appears, then, that the human skeleton found is referable to a late Palæolithic epoch, and cannot claim a pre-chalky boulder clay antiquity. I wish to take this opportunity to state that those who opposed my contention as to the great age of these remains were in the right, while the views held by me regarding them have been shown to be erroneous."

The Swiney Lectures on Geology, 1916.—The Trustees of the British Museum (Natural History) announce that a course of twelve lectures on the Mineral Resources of Europe (illustrated by lantern slides) will this year be delivered by Dr. John S. Flett, F.R.S., at the Royal Society of Arts, 18 and 19 John Street, Adelphi, W.C. (by permission of the Council of the Society). The lectures will be given on Tuesdays, Thursdays, and Fridays, at 5 p.m., beginning Tuesday, November 14, and ending Friday, December 8. Admission free.

Errata and Addendum to Mr. Leonard Hawkes's abstract of paper read at British Association (see Geol. Mag. for October): p. 468, l. 10, *for* Borganfjord *read* Borgarfjord; l. 11, *for* Bernfjord *read* Berufjord; p. 469, l. 8, *for* ice-scratched boulder *read* ice-scratched liparite boulder.

Errata in Mr. P. G. H. Boswell's abstract, October, pp. 466–7: § 1, l. 5, *for* rise above 0·5 per cent *read* rise above 0·02 per cent, and (two lines lower) *for* 0·02 per cent *read* 0·5 per cent. § 3: the opening paragraph should read: "as simple as possible; the sand ought to contain only quartz." In the next paragraph the fourth sentence should read: "The important supplies of glass-sands occurring in Western Europe are all associated with planty material. Lippe sand occurring with rafts of braunkohle." For the locality Hohenboka *read* Hohenbocka, and *for* Berrythorpe *read* Burythorpe.